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# Nationwide Urban Runoff Program
# Tampa, Florida: Phase 3 Final Report
# Volume 2. Stormwater Management Plan Appendices

Tampa Dept. of Public Works, FL

Prepared for

Environmental Protection Agency, Washington, DC

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CITY OF TAMPA

TAMPA, FLORIDA 33602

# TAMPA NATIONWIDE URBAN RUNOFF PROGRAM
## PHASE III FINAL REPORT
## VOLUME II
## STORMWATER MANAGEMENT PLAN
## APPENDICES

October, 1983

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This report lists the Appendices contained in the volume, as follows: A. Mathematical Models; B. Drainage Ordinances; C. Design Criteria; D. Drainage System Design; E. Operations and Maintenance; F. Long-Term River Monitoring; and G. Long-Term Rainfall/Runoff Monitoring. Appendix A describes in detail the mathematical models used in development of the Stormwater Management Plan, and Appendices B. thru G. re-evaluate the City's present approaches to stormwater management including those listed, with respect to the overall objectives of the Stormwater Management Plan.

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October 31, 1983

J-7738

Mr. Ron Giovanelli
City of Tampa
Department of Public Works
City Hall Plaza - 4th Floor
Tampa, Florida 33602

Dear Mr. Giovanelli:

In accordance with our Agreement dated July 6, 1981 and subsequent amendments, we are pleased to submit the Phase III Final Report, Stormwater Management Plan for the Tampa Nationwide Urban Runoff Program Study.

Results and findings of the Tampa Nationwide Urban Runoff Program and Receiving Water Study are presented in five (5) final reports including Appendices and fourteen (14) individual task outputs. Included among the final reports are:

1. Phase I Receiving Water Study,
2. Phase II Final Report,
3. Phase III Stormwater Management Plan,
4. Lower Hillsborough River Report, and
5. Final Summary Report.

This study was conducted by Messers. David R. Bingham and Paul N. Singarella and Ms. Katherine O. Thompson of Metcalf & Eddy, under the direction of Dr. Abu M. Z. Alam. Apendices B, C, E and G were prepared from information provided by Priede-Sedgwick staff under the supervision of Mr. Nilo Priede.

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New York · Palo Alto · San Bernardino · [illegible] · [illegible] · Chicago · Houston · Atlanta · Somerville NJ · Silver Springs MD · Honolulu

We thank you for the cooperation and assistance which you have provided to us during the conduct of the work. It has been a pleasure to work for the City on this important project. We look forward to our continued association with the City of Tampa on future assignments.

Very truly yours,

Abu M. Z. Alam

Abu M.Z. Alam
Associate

AMZA:fpc

# PHASE III
# CITY OF TAMPA STORMWATER MANAGEMENT PLAN (VOLUME II)
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LETTER OF TRANSMITTAL

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# INTRODUCTION

Table 1 lists the Appendices contained in this Volume and the contractor responsible for the content and format of each. Appendix A describes in detail the mathematical models used in development of the Stormwater Management Plan (SMP). Appendices B through G reevaluate the City's present approaches to stormwater management including drainage ordinances, design criteria, drainage system design, operations and maintenance and stormwater and receiving water monitoring with respect to the overall objectives of the SMP. The suggested modifications to existing practices emphasize appropriate design conditions and the coordination of quantity and quality considerations.

TABLE 1. STORMWATER MANAGEMENT PLAN APPENDICES, TITLES AND RESPONSIBILITY

| Designation Title | | Responsibility |
|---|---|---|
| A. | Mathematical Models | Metcalf & Eddy |
| B. | Drainage Ordinances | Priede-Sedgwick |
| C. | Design Criteria | Priede-Sedgwick |
| D. | Drainage System Design | Metcalf & Eddy |
| E. | Operations and Maintenance | Priede-Sedgwick |
| F. | Long-Term River Monitoring | Metcalf & Eddy |
| G. | Long-Term Rainfall/Runoff Monitorig | Priede-Sedgwick |

# APPENDIX A

## MATHEMATICAL MODELS

### General

In this Appendix, the three numerical models used during the Tampa NURP study are described. These models include the Storm Water Management Model (SWMM) (1) as modified by Metcalf & Eddy, Inc, the Simplified Storm Water Management Model (S/SWMM) (2) and the Water Quality in Open Channel Networks Model (WQON) (3).

### SWMM

SWMM is a comprehensive, deterministic model which simulates stormwater runoff quantity and quality. The basic input which drives SWMM is the design storm event described by a hyetograph. Once the design storm is selected, the physical processes which route the flow and quality through the drainage system are divided into two "Blocks": the Runoff Block, which simulates surface runoff processes and the Transport Block, which simulates collection system processes, and produces results in the forms of time-varying quantity (hydrographs) and quality (pollutographs) values. These blocks are described below. Figure A-1 illustrates a schematic of how SWMM represents a storm sewer typical of the subbasins simulated.

Runoff Block. Existing drainage patterns are used to discretize the subbasins into subcatchments on the order of 1 to 40 acres in size. The area and shape, percent impervious area, ground slope, surface resistance factors, surface storage factors

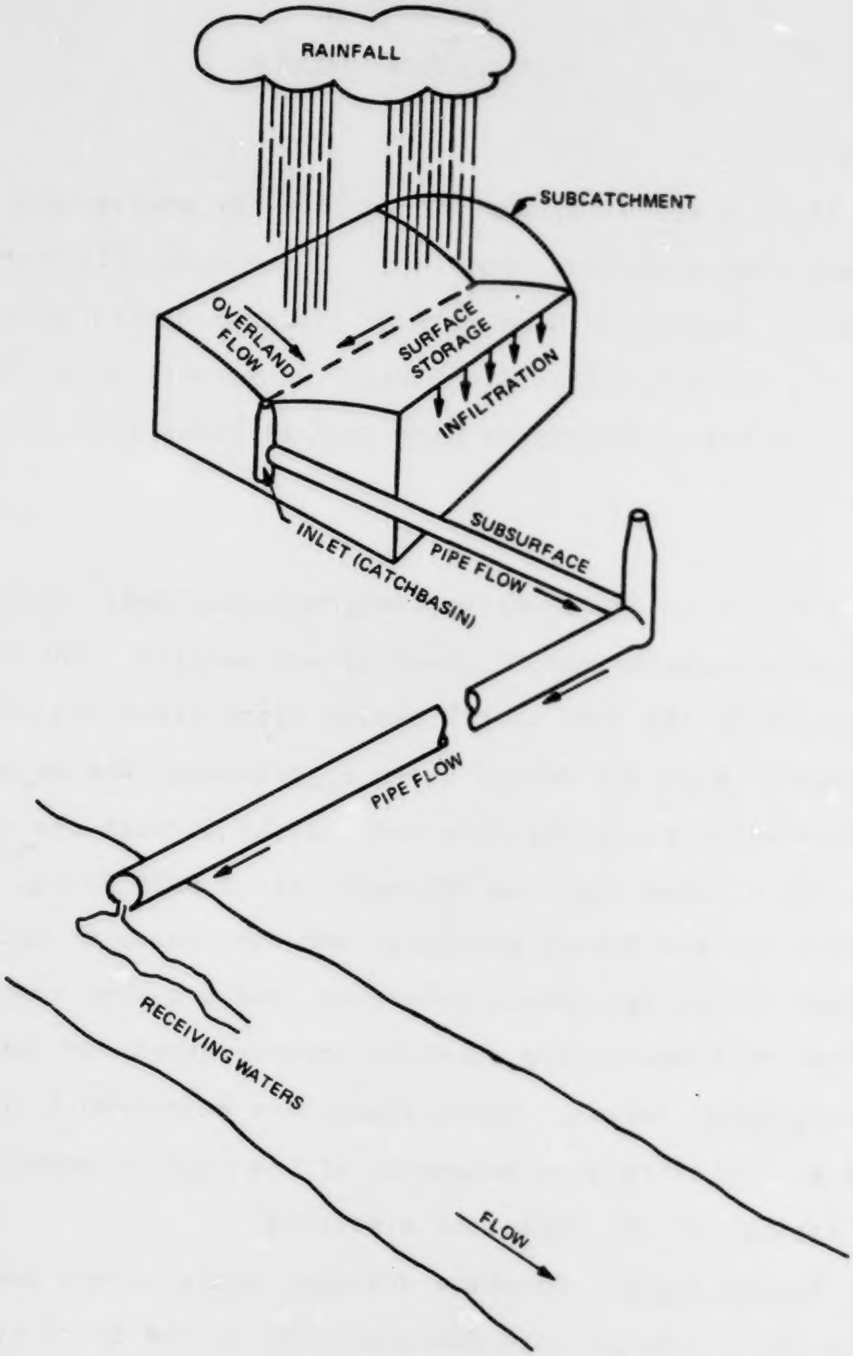
RAINFALL
SUBCATCHMENT
OVERLAND FLOW
SURFACE STORAGE
INFILTRATION
INLET (CATCHBASIN)
SUBSURFACE PIPE FLOW
PIPE FLOW
RECEIVING WATERS
FLOW

FIG. A-1 SCHEMATIC DIAGRAM OF STORM SEWER SYSTEM AS REPRESENTED IN SWMM and infiltration rates are defined for each subcatchment. After the subcatchments are defined, they are divided into the separate land uses which exist within their boundaries. SWMM allows inputs of the following five land uses:

- low density residential,
- high density residential,
- commercial,
- industrial, and
- open/natural.

The street sweeping frequency, number of sweeping passes, number of dry weather days before a storm, and surface pollutant accumulation rates for each land use are also input to SWMM. These are used in conjunction with land use and gutter length to compute the amount of surface pollutants accumulated before the design storms.

It was judged that for small and moderate storms, runoff from pervious areas (grasses and open space) would be small. For this reason, the infiltration rate was initially set high and was simulated in the SWMM using the Horton equation. The initial rate was 3.0 inches per hour decreasing to a minimum of 0.5 inches per hour. The surface storage (ponding) on pervious areas was initially set at 0.25 inches. These two factors were adjusted in each basin, when required, in the calibration of runoff peaks and volumes.

Surface storage on 75 percent of the impervious areas (roofs and pavements) was initially judged to be 0.06 inches. No

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surface storage was allowed on the remaining 25 percent. This parameter was also considered a candidate for adjustment during the calibration process. Parameters such as percent impervious surface, ground slope, and land use, were based on the data on basin characteristics which were collected during Phase II (4), and are generally not expected to be adjusted during the calibration process.

At the beginning of the rainfall event, the portion of the rain which becomes runoff carries surface pollutants into the collection system to be tranported downstream. Once the program has calculated the quantity and quality of surface runoff, it proceeds to the Transport Block.

Transport Block. The Transport Block describes the flow in the stormwater drainage system and the pollutants carried by the flow. The major input data consists of the physical description of the collection system including the size, slope and roughness coefficients for storm sewers and ditches. Details of the drainage system were also determined from previous Phase II outputs (4). Generally, pipes and ditches 12 inches and larger are modeled.

The following hydraulic parameters were used in the SWMM during the Tampa NURP study:

Surface retention storage

a. impervious areas: 1/16 to 3/8 inch

b. pervious areas: 1/4 to 3.0 inch

Ground infiltration, as used in Horton's Equation

a. maximum rate: 3.0 inch/hour

b. minimum rate: 0.52 inch/hour

c. exponential decay rate: 0.00115 $sec.^{-1}$

Flow friction factors (n) as used in Manning's Equation

a. Overland flow
  - impervious surfaces: 0.013
  - pervious surfaces: 0.25

b. concrete sewers: 0.0153

c. ditches: 0.022

Using the physical characteristics of the sewer sytem as described above, the Transport Block routes the stormwater quantities computed by the Runoff Block through the collection system and produces output hydrographs and pollutographs which describe the variation in outflow quantity and quality over time. The characteristics of the stormwater are computed for the most downstream element in a particular basin.

Flow, five day biochemical oxygen demand ($BOD_5$), total suspended solids (TSS) and total coliform bacteria were simulated in the Runoff and Transport Blocks. BOD and coliform quantities in stormwater are computed by SWMM as a function of solids accumulation and washoff in each basin. The stormwater quality parameters established for each basin during the calibration process are given in Table A-1.

S/SWMM

The input data which drive the S/SWMM consist of rainfall records. In order to effectively manage areas as large as the

## TABLE A-1. STORMWATER QUALITY PARAMETERS OF SUBBASINS ESTABLISHED DURING CALIBRATION OF SWMM

| Basin | Land use[1] | Percent land use in basin | Dust and dirt per 100 ft. gutter, (lbs.) | Soluble BOD per lb dust and dirt (mg/gm) | Non-soluble BOD[2] | Coliform multiplier[3] |
|---|---|---|---|---|---|---|
| J.L. Young | 2 | 100 | 0.05 | 20 | 0.2 | 5.0 |
| Wilder Ditch | 1 | 51 | 0.04 | 50 | 0.6 | 1.0 |
| | 2 | 24 | 0.18 | 77 | | |
| | 3 | 7 | 0.26 | 30 | | |
| | 4 | 17 | 0.08 | 50 | | |
| North Jesuit | 1 | 58 | 0.5 | 25 | 0.25 | 1.0 |
| | 4 | 42 | 2.2 | 38 | | |
| Charter & Harding | 1 | 90 | 0.04 | 10 | 0.10 | 5.0 |
| | 4 | 10 | 0.08 | 10 | | |
| Norma Park | 1 | 7 | 0.01 | 5.0 | 0.05 | 5.0 |
| | 3 | 93 | 0.02 | 7.7 | | |
| SWMM Default Values | 1 | - | 0.7 | 5.0 | 0.05 | 1.0 |
| | 2 | - | 2.3 | 3.6 | | |
| | 3 | - | 3.3 | 7.7 | | |
| | 4 | - | 1.5 | 5.0 | | |

1. Single family residential = 1, multi family residential = 2, commercial/institutional = 3, open space = 4.
2. Fraction of dust and dirt that is non-soluble BOD.
3. Multiplier used for coliform calibration.

lower Hillsborough River basin, the processes which translate the rainfall into runoff and potential overflows are simplified compared with those of the SWMM.

S/SWMM calculates the quantity and quality of runoff, the effect the in-system storage may have on the amount of runoff, and the volume and pollution load of stormwater overflows. This was done for each subarea within the study area on an hourly basis for the duration of the design storm runoff. The S/SWMM is illustrated in Figure A-2.

Development of flows and loads using S/SWMM requires that the hourly precipitation for the design storm be specified and that the overall drainage area be discretized into subareas. Further, the subareas must be assigned input values for the following:

1. Runoff coefficient,
2. Outflow capacity,
3. Storage volume,
4. Pollutant concentration.

Given these inputs, S/SWMM will predict overflow occurrence, volume and pollutant load to the receiving waters from each subarea. The following is a description of each component of S/SWMM and how the input values were generated. Pertinent subarea characteristics are presented in Table A-2.

Rainfall - Design storms were developed for both quantity (large return period) and quality (small return period) impact studies. Flows and loads were generated for these design storms.

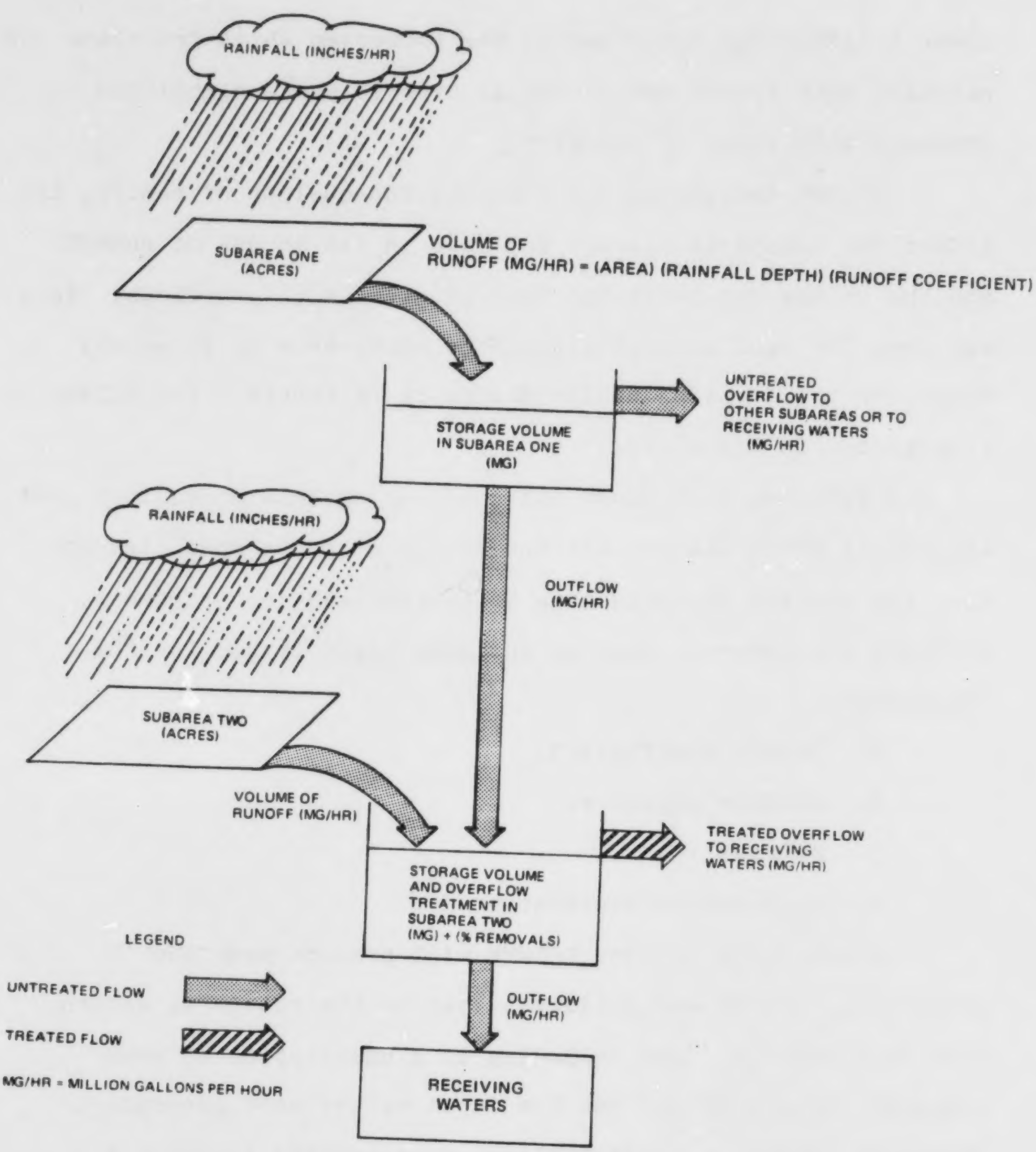
RAINFALL (INCHES/HR)
SUBAREA ONE (ACRES)
VOLUME OF RUNOFF (MG/HR) = (AREA) (RAINFALL DEPTH) (RUNOFF COEFFICIENT)
STORAGE VOLUME IN SUBAREA ONE (MG)
UNTREATED OVERFLOW TO OTHER SUBAREAS OR TO RECEIVING WATERS (MG/HR)
RAINFALL (INCHES/HR)
OUTFLOW (MG/HR)
SUBAREA TWO (ACRES)
VOLUME OF RUNOFF (MG/HR)
TREATED OVERFLOW TO RECEIVING WATERS (MG/HR)
STORAGE VOLUME AND OVERFLOW TREATMENT IN SUBAREA TWO (MG) + (% REMOVALS)
LEGEND
UNTREATED FLOW
TREATED FLOW
MG/HR = MILLION GALLONS PER HOUR
OUTFLOW (MG/HR)
RECEIVING WATERS

FIG. A-2 SCHEMATIC DIAGRAM OF COMPONENTS OF S/SWMM MODEL

TABLE A-2. S/SWMM SUBAREA CHARACTERISTICS FOR THE EXISTING STORMWATER SYSEM WITH PROJECTED LAND USE

| Subarea No. | Subarea Name | Abbreviation | Runoff Area (acres) | Runoff Coefficient | Effective Runoff Area (acres) | Storage (mgal) | Outflow (mgal/hr) |
|---|---|---|---|---|---|---|---|
| 1. | North Tampa | NT | 929 | .45 | 418 | 13.22 | 1.00 |
| 2. | Seaboard Coastline | SC | 811 | .56 | 454 | 8.32 | 2.00 |
| 3. | Sulphur Springs | SS | 502 | .47 | 236 | .77 | 10.70 |
| 4. | River Bend | RB | 873 | .43 | 375 | .62 | 27.43 |
| 5. | Forest Hills | FH | 1524 | .51 | 777 | 14.00 | 5.87 |
| 6. | Seminole Heights | SH | 575 | .43 | 247 | .46 | 7.55 |
| 7. | Northwest Tampa | NW | 1160 | .39 | 452 | 31.44 | .99 |
| 8. | Kirby Creek | KC | 1131 | .41 | 464 | 6.17 | 14.12 |
| 9. | Oak Grove | OG | 469 | .38 | 178 | .95 | 20.25 |
| 10. | Hillsborough Ave. | HA | 992 | .46 | 456 | 3.54 | 5.97 |
| 11. | Wellswood | WW | 666 | .48 | 320 | .55 | 18.19 |
| 12. | Sunshine Park | SP | 856 | .42 | 360 | .48 | 17.96 |
| 13. | St. Joseph's | SJ | 1022 | .47 | 480 | 13.08 | 13.94 |
| 14. | Tampa Heights | TH | 1071 | .44 | 471 | 5.30 | 4.60 |
| 15. | West Tampa | WT | 898 | .43 | 386 | .82 | 9.24 |
| 16. | University of Tampa | UT | 657 | .59 | 388 | .58 | 33.00 |
| 17. | Downtown | DT | 525 | .63 | 331 | .57 | 39.59 |

Drainage Area Discretization - The surface area that drains each subarea was input to the model in acres. The overall study area was represented in S/SWMM as 17 distinct subareas, each outflowing and overflowing directly to the River, in accordance with the City of Tampa Map entitled "Storm Drainage." The subareas used as input to the S/SWMM were shown in Figure A-2.

Runoff Coefficient (Rc) - A volumetric runoff coefficient is used to determine the percentage of rainfall volume in each subarea that is converted to runoff. Subarea runoff coefficients were determined as a function of projected land use as given in City of Tampa Preliminary Subsector Plans, Tampa 2000 Land Use Element. A runoff coefficient for each land use was assigned based on analysis of the detailed storm event and percent imperviousness data available from a related study (4). These runoff coefficients are presented in Table A-3. A more detailed explanation of their development is available elsewhere (1).

TABLE A-3. RUNOFF COEFFICIENTS DERIVED FOR VARIOUS LAND USES

| Land Use | Runoff Coefficient |
|---|---|
| Commercial/Industrial | 0.90 |
| High Density Residential | 0.68 |
| Medium Density Residential | 0.53 |
| Low Density Residential | 0.37 |
| Institutional | 0.31 |
| Open/Natural | 0.20 |

Based on these coefficients, the subarea runoff coefficients as listed in Table A-2 were calculated from the Subsector Land Use Maps. The values range from 38 percent in less developed areas to 63 percent in central urban areas. The runoff coefficient for each area is assumed to remain constant over time.

Storage Volume - Each subarea has potential for storage that may alter the amount and timing of runoff leaving the subarea. This storage consists of the volume in pipes, ditches and retention ponds which must be filled before an overflow can occur. An estimation of pipe and ditch length in each subarea was made based on Map C, City Storm Drainage. Retention pond surface area was determined from Map E, Stormwater Retention Areas in the City of Tampa. Storage was input in each subarea as volume in million gallons.

Outflow Capacity - The outflow rate is the rate at which runoff is discharged from the drainage network. Outflow volume can be routed into another subarea or directly to the receiving water. In the lower Hillsborough River basin subareas, all major outflows lead directly to the River. The number and size of the major outfalls from each subarea were determined from the City of Tampa map entitled Major Outfalls and from information provided by the City. This enabled determination of subarea outflow capacities. If the subarea outflow capacity is exceeded, the volume fills available storage and eventually overflows.

Overflows - Overflows occur in a subarea when, in any hour, the storage capacity and outflow rate are exceeded. Overflows in the lower Hillsborough River basin subareas are all routed directly to the River. The rate of overflow in million gallons per hour is calculated by the model and depends on the rainfall rate, the subarea characteristics and the amount of runoff.

Pollutants - The concentration of pollutants is input to the model in milligrams per liter for all pollutants except total coliform, which is input in units of Most-Probable-Number per 100 milliliters (MPN/100 ml). The three pollutants studied were total suspended solids (TSS), ultimate biochemical oxygen demand (BOD), and fecal coliforms.

### WQON

WQON is a numerical model which has the capability of predicting hydrodynamics and transient water quality in an estuary. The model represents the estuary as a one-dimensional (cross-sectionally averaged) system. WQON has the capability of solving for several water quality constituents, including salinity, BOD, DO and coliform bacteria. The numerical solution procedures for WQON are based on the method of weighted residuals, which is an application of the finite element technique.

The WQON modeling approach involves three steps as follows:

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1. Simulate hydrodynamics (tide and velocity variations).
2. Simulate salinity (and the effect of density variations on hydrodynamics).
3. Simulate water quality.

In the second step, where salinities are simulated, the hydrodynamic results are modified because of a coupling in the model between hydrodynamics and salinity. This coupling accounts for the effect of salinity (and thus density) variations on the cross-sectionally averaged velocities. Once these steps are completed, water quality parameters such as BOD and DO may be simulated.

The program requires specification of the following:

1. DO Saturation Level;
2. Initial Conditions,
    1. Water Surface Elevations along the River,
    2. Background Concentration of Quality Constituents along the River;
3. Boundary Conditions,
    1. Downstream Table of Tidal Elevations and Quality of Incoming Tide,
    2. Upstream Quantity and Quality,
    3. Benthic Demand,
    4. Lateral Inflow Quantity and Quality.

The determination of these is described in detail in Chapter 3.

## REFERENCES

1. Metcalf & Eddy, Inc., University of Florida, and Water Resources Engineers, Inc., Storm Water Management Model, Volumes I-IV, Environmental Protection Agency, Water Quality Office, 1971.

2. Metcalf & Eddy, Inc., Development and Application of a Simplified Stormwater Management Model, Environmental Protection Agency, Water Quality Office, 1976.

3. Dailey, J.E., and Harleman, D.R.F., Numerical Model for the Prediction of Transient Water Quality in Estuary Networks, Massachusetts Institute of Technology, Technical Report No. 158, October, 1972.

4. Priede-Sedgwick, Inc., Detailed Event Data, Task II.5 and II.8, Tampa Nationwide Urban Runoff Program Study, Phase II, April, 1983.

5. Metcalf & Eddy, Inc., Phase II Report, Task II.6 Runoff Characterization, Task II.9 Control Testing, Task II.10 Projection of Study Area-Wide Loadings, Tampa Nationwide Urban Runoff Program Study, Phase II, October, 1983.

# APPENDIX B

# DRAINAGE ORDINANCES

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# SECTION 1

# REVIEW OF EXISTING ORDINANCES

## Introduction

Erosion, sediment control, hydrologic and hydraulic studies, flood plains, best management practices -- these and other drainage concepts are receiving substantial public attention in many areas throughout the country. Advances gained through research and experience are allowing engineers to utilize more sophisticated approaches for urban drainage problems. Unfortunately, drainage ordinances in most municipalities were enacted many years ago using technologies and techniques developed before 1965 and concentrated primarily on flood control. These ordinances contain limited information describing recent advances in urban drainage theory and practice employed by those communities having hard-earned experience in urban drainage.

During the early 1960's, the City of Tampa was very concerned with urban drainage due to extensive flooding brought about by abnormally wet weather. However, during the last 19 years the City has experienced relative dry conditions and the focus of concern with drainage problems has shifted. The environmental movement of the 70's focused attention on the quality of water as well as the quantity. Additionally, development of the high speed digital computer has enabled engineers and stormwater management officials to develop and use computer simulation models for evaluating both quantity and quality impacts resulting from urban stormwater runoff. While the City of Tampa has become acquainted with new techniques and applied these techniques to the problems at hand, the City ordinances dealing with stormwater have only been modified on a piecemeal basis.

This report reviews the six sections of City Code which address various aspects of stormwater drainage and serve in lieu of a drainage ordinance. Unfortunately, the City of Tampa code does not presently deal with drainage problems in a unified section. This document examines the six existing ordinances and presents a cumulative critique with respect to scope, effectiveness, and clarity. Specific recommendations are presented for addressing a variety of issues not presently contained in the numerous ordinance sections concerning drainage. Finally, based on an evaluation of a number of drainage ordinances throughout the country, a model ordinance is presented for the City's consideration.

The development of an urban drainage management program requires three principal components: a Unified Drainage Ordinance, a Drainage Engineering Manual, and a competent staff. The City of

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Tampa has already developed a competent drainage engineering staff which has, through policy and management decisions, started developing a Drainage Engineering Manual. The City should also concentrate upon developing a modern, urban Unified Drainage Ordinance.

Before any community drafts and adopts a drainage ordinance, outstanding and unsolved problems should first be reviewed. The community should identify the problem areas which the ordinance will attempt to address and some basic decisions should be made concerning the community's philosophy for dealing with drainage problems. The general format of the drainage ordinance is still another consideration that must be answered. These and other concerns are discussed in this technical memorandum.

## Sub-Divisions Ordinance

Tampa's Sub-Divisions Ordinance has been codified as Chapter 35 of the City of Tampa Code. The chapter is divided into seven articles and was adopted by City Council as a set of regulations to guide and coordinate subdivision development with the city. Subdividing land is the first step in orderly community development. However, once land has been subdivided and recorded as streets, lots, and blocks, correcting or modifying defects is costly and difficult. Subdivided land sooner or later becomes a public responsibility. Roads, streets, and drainage systems must be maintained and a variety of related public services customary to urban areas must be provided. The welfare of the entire community is thereby affected in many important respects by subdivision development. Given this recognition, the best interest of the public, the developer, and the future lot owners are maintained when subdivisions are conceived, designed, and developed in accordance with sound rules and proper minimum standards. Standards and regulations are designed to ensure that the constructed subdivision will be consistent with the desirable development of the City by securing a coordinated layout of the subdivision with adequate provisions for traffic, light, air, recreation, transportation, water, drainage, sewer, and other public facilities. Portions of the existing ordinance which are pertinent to drainage are as follows:

| | |
|---|---|
| Section 35-9(8): | Requirement that one sheet of the preliminary plat show existing and proposed elevations of the site as well as drainage boundaries, drainage areas, and existing and proposed drainage facilities (storm sewers, ditches, culverts) and means of disposal of stormwater. |

Section 35-30: Provides for a review of drainage plans on the preliminary plat by a Subdivision Review Committee which includes a representative of the Department of Public Works.

Section 35-41: Requirements for the form and content of the drainage plan which includes the following: drainage construction plans, drainage calculations and other data necessary to support construction and drainage plans. These plans must be submitted in standard form and as required by the City's Department of Public Works at a graphic scale of one inch equals twenty feet.

Section 35-42: Provides for drainage review of final plat drawings (and subsequent modifications as required) by the Subdivision Review Committee and establishes the number and media for submission of final engineering construction drawings.

Section 35-54: Establishment of the general requirements for minimum design standards. Specific segments applicable to drainage include --

- All proposed subdivisions shall conform to the comprehensive plan of development or elements thereof, as may have been adopted by the Planning Commission and approved by Tampa City Council.
- The land proposed for subdivision use shall be suitable for development and shall not be subject to flooding, poor drainage, erosion, or other conditions detrimental to health, safety, and general welfare of the public. Included in this criteria are the following topics: significant increases in flood flows, heights, or damages; impacts to the storage capacity of the flood plain; conditions for utilization of site adjacent to the flood plain flood way areas by elevations at least two feet above the regulatory flood level or other provisions; requirement for the elevation of building floors for living spaces at a minimum of 1.5 feet above the elevation of the center of the street pavement adjacent to the building; and, requirements that the developer construct a drainage system to meet required standards

when the existing drainage system is inadequate.

- To the fullest extent possible subdivisions shall be designed so as to conform to and take advantage of the topographic and other natural features of the land.
- A soil investigation report shall be submitted with construction plans and shall contain information adequate to support the design of streets, drainage facilities, utilities, buildings, and other facilities.

Section 35-57(b): Definition of minimum utility easement widths and requirements.

Section 35-59: Establishment of minimum design criteria for drainage systems. Specific items addressed include:

- Drainage plan -- minimum requirements for drainage plan drawings must include topography, established State and City drainage boundaries, drainage boundaries or proposed conduit and inlet designs, size of each drainage area, existing and proposed zoning, existing and proposed drainage facilities, and, a graphic scale not greater than one inch equals two hundred feet.
- Drainage design criteria - requirement that drainage designs be based on specific design criteria unless conditions indicate that such criteria should be modified as approved by the Department of Public Works. Specific design criteria include: runoff coefficients, rainfall data sources, design basis for conduit and inlets, design basis for retention basins with and without positive outfalls, runoff generation methods, pipe and ditch hydraulic design basis, and minimum pipe size criteria.
- Definition of graphic scale standards for plan and profile sheets required for all storm sewer, ditch, and other drainage facilities construction.

- Requirement that standard design be utilized for inlets and manholes and that special drainage structures, when necessary, be approved by the Department of Public Works.
- Reference to regulations pertaining to draining, filling, excavation, and/or removal of soil or earth products.

Section 35-75: Requirement that the owner provide and construct adequate storm drainage facilities to: (1) provide for the collection and disposal of stormwater generated on site and (2) the passage of stormwater through the subdivision which accumulates from drainage areas up-stream of the subject site. Further, the drainage facilities shall be designed in accordance with the minimum design standards set forth by City ordinances, established engineering principles and practices, and standards of the Department of Public Works.

## Zoning Ordinance

Zoning is perhaps the most widely used method of enforcing land use requirements within a city's comprehensive growth plan. These legal and administrative processes allow the community protection against indiscriminate land uses. In technique and concept, zoning is a simple division of land into districts having different uses and density regulations. Zoning functions as the instrument for guiding the use of land in the future and for protecting existing uses which conform to the overall aims of the city's comprehensive growth plan.

Tampa's Zoning Ordinance is contained in Chapter 43 of the City of Tampa Code. Indirectly, many aspects of this chapter have an impact on the drainage program for the City. Sections of this chapter directly regulate the physical factors which impact the drainage system, including: minimal lot size; open space requirements; density limitations; and set-back requirements. In addition, recognition is provided for use limitations in areas which are conservation zones, wetland areas, and flood plains but specific areas are not defined within the City Code..

Section 43-61 of the Code goes beyond these general requirements and directly impacts the City's drainage problems by limiting development in the Curiosity Creek drainage system. Presently, within this sixty acre area located generally above elevation 28,

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no building or structure may be set, constructed, or moved to or within this flood plain/drainage retention area.

## Building and Building Regulations Ordinance

A broad variety of construction activities are covered under the Buildings and Building Regulations Ordinance, Chapter 45 of the City Code. Two articles of this code have significant impact on the city's drainage system: Article XV which addresses earth moving; and Article XVI which addresses flood damage control.

Earth moving, specific grading, filling, and/or excavation of soil and earth products can have a profound effect on the historic drainage patterns and storage capacities within a basin. Improper grading, filling, and/or excavation can result in a public nuisance which can impact a few private citizens or create conditions detrimental to health, safety, and general welfare of the public. Article II, Section 45-28 addresses site grading plans and requires that proposed drainage plans be submitted, reviewed and approved prior to issuance of the building permit. Further, this section provides that drainage plans will be coordinated with and approved by all agencies concerned with local and regional drainage.

Article XV, Section 45-396 of the City Code, specifically addresses design standards, construction methodology, and permit requirements for detention/retention ponds and all other excavation types. Specific criteria included in this section are: set-back requirements for property line for all excavations, suitable side slopes, grassing and mulching requirements, and fencing requirements. This section also provides that no excavation shall detract from or interfere with the ultimate drainage plans or existing patterns of the city and/or county. Further, all plans for proposed excavations shall be required to bear the seal and signature of an engineer registered and licensed by the State of Florida and shall show a positive outfall of stormwater drainage overflow into a City and/or County drainage system.

Article XVI is the Flood Damage Control Ordinance which was adopted by the City of Tampa on December 20, 1977, in order to qualify for Federal Flooding Insurance. This standarized ordinance impacts the overall Buildings and Building Regulations Ordinance in the following five areas:

- Restriction or prohibition of land uses which are dangerous due to water, erosion, or flood heights and velocities.

- Requirement that land uses vulnerable to floods (including facilities which serve such uses) be protected against flood damages at the time of initial construction.
- Control of the alteration of natural flood plains, stream channels, and natural protective barriers which are involved in the accommodation of flood waters.
- Control of filling, grading, dredging, and other development which may increase erosion or flood damage.
- Prevention and regulation of construction of flood barriers which will unnaturally divert flood waters or which may increase flood hazards to other lands. The objective of this section is to protect the City's inhabitants and infrastructure systems from damage due to flooding and surge tides during and after inclement weather. Included in this section are the adopted Flood Insurance Rate Maps and building code requirements which have been developed by the Federal Emergency Management Agency.

Section 45-28 of this ordinance regulates site drainage and grading plans. This section of the Code requires that prior to the issuance of a construction permit for additions or improvements to any building or structure with exception of single family residences (including paved, graded, and landscaped areas), a comprehensive site drainage and grading plan together with a copy of drainage calculations shall be submitted to the Department of Public Works for review and approval. The section also describes the coordination between the Department of Public Works, the Southwest Florida Water Management District, and the Department of Transportation and defines the type of information which must be shown on the proposed plans.

Plumbing Ordinance

Section 50 of the City of Tampa Plumbing Code contains the City's Plumbing Ordinance which establishes the fundamental City regulations for connecting water, wastewater, and stormwater piping to the city's infrastructure systems. Four specific sections are related to drainage in an indirect fashion:

Section 50-77: Regulates the use of sanitary sewers for stormwater drainage and specifically prohibits the connection of building gutters and roof stormwater drains to the sanitary sewer system.

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| Chapter 50, Division 2: | This section regulates the issuance of plumbing permits for the purposes of water supply, wastewater disposal, and stormwater drainage. |
| Chapter 50, Division 7: | This section of Code regulates the design, review of plans, and construction of storm drains and provides for certification and examination of contractors. |
| Chapter 50, Division 8: | This section provides for the regulation of indirect and special waste pipes (swimming pool drains). Sections 50-198 and 50-199 describe the procedures required for application for a permit from the plumbing inspector, minimum information to be shown on plans and specifications, and minimum requirements for waste disposal from a swimming pool. |

## Boats, Docks, and Waterways Ordinance

Indirectly, the Boats, Docks, and Waterways Ordinance, Chapter 10 of the City Code, regulates the material which can be discharged into sewers (wastewater systems are not distinguished from stormwater systems). Section 10-29 specifically prohibits any person or business entity on the shore, wharf, manufacturing establishment, or mill of any kind, to allow trash, garbage, debris, acids, timber, logs, lumber, or refuse matter of any kind or description whatsoever to enter into any navigable waters lying within the corporate limits of the City, or into any tributary of any such navigable water which would eventually be washed into navigable waters.

## SECTION 2

## CUMULATIVE CRITIQUE OF ORDINANCES

The critique presented in this section is based upon an ideal approach to developing an urban storm drainage program. This approach, touched upon briefly in Section 1, contains five steps which traverse the chasm between the problem areas that Tampa currently faces and satisfactorily administrating the drainage program by the City staff. The first step in this process is identifying problem areas in the City's drainage program. Tampa has a number of unique and challenging problem areas which the citizens, elected public officials, and staff have identified in a number of different manners. These problem areas must be considered and dealt with while developing the Drainage Ordinance and the companion Drainage Engineering Manual.

The second step involves developing objectives for the Drainage Ordinance and Drainage Engineering Manual. The objectives of the ordinance and the drainage program itself represent the community's philosophy for dealing with the identified problems. These objectives may also be considered the goals of the ordinance and the drainage program.

The third step entails developing a unified drainage ordinance appropriate for the City and one which can be implemented within the existing bureaucratic structure. The drainage ordinance adopted by the City should essentially be an elaborate statement of public policy for dealing with the City's drainage problems. The drainage ordinance must be officially adopted by the governing body and, as a result, the political process becomes the controlling force behind the ordinance. Therefore, the ordinance must be designed to express the City's drainage control philosophy and must be concise enough to aid the elected officials in executing their responsibilities. Elected officials should not be dealing with engineering criteria or design standards. The elected officials should determine the overall policies and not be particularly concerned with the administrative aspects of the drainage program except as those elements relate to budgetary control. Therefore, in order to make the drainage ordinance a viable part of the political process, the document will serve strictly as a policy statement for the City and technical details will be included in a companion technical document.

The fourth step is the preparation and adoption of a Drainage Engineering Manual (DEM) which deals specifically with the engineering and technical details associated with the policies established in the Drainage Ordinance. In formulating the drainage program, the development and adoption of the ordinance would preceed writing any companion technical or engineering documents. The Drainage Engineering Manual would contain the technical and engineering requirements and design criteria needed to administer the Drainage Ordinance.

Finally, the fifth step involves developing a staff which is technically competent and familiar with the Drainage Ordinance and the Drainage Engineering Manual. This staff will be responsible for the day-to-day administration of the ordinance, review of both residential and commercial drainage problems, and application and updating of the manual.

These five conceptual steps are required to implement the ideal drainage program. With this perspective, a cumulative critique of current City Code sections was undertaken.

## Scope and Content

The first observation concerning drainage ordinances is that there is no single drainage ordinance on the books. However, drainage is dealt with through four other ordinances: Subdivisions, Zoning, Buildings and Building Regulations, and Plumbing Ordinances. A single, unified drainage ordinance which comprehensively covered the City's policy on drainage would be helpful to City Staff, developers, and design professionals involved with drainage projects in Tampa.

The Subdivisions Ordinance (Chapter 35) is generally a well written ordinance which, typical of many ordinances in the State of Florida, provides a combination of policy, procedure and design criteria statements within one ordinance. As stated previously, the Drainage Ordinance should establish public policy through clear policy statements and specific procedures and design criteria should be collected and contained in the Drainage Engineering Manual. Additional comments on the subdivision ordinance are as follows:

- Article One contains appropriate authority and applicability clauses as well as a statement of policy on subdividing lands in Tampa. Additionally, Section 35-6 contains an adequate definition of terms used in the ordinance to avoid confusion in subsequent portions of the ordinance.

- Article Two establishes the general procedures to be used in submitting of preliminary and final plats including the information required and the form of both documents. This article would not detract from a unified drainage ordinance but would serve to compliment the ordinance.

- Article Three establishes the minimum design standard for subdivisions in Tampa. This article contains a number of policy statements which would be appropriate for the unified drainage ordinance but, unfortunately, the article also contains a large number of drainage design criteria and procedures which would be handled more effectively in the Drainage Engineering Manual.
- Article Four establishes the minimum improvements required for a subdivision in the City and states the policy that the owner shall provide and construct adequate storm drainage facilities to deal with the stormwater generated on his site, as well as pass the stormwater of lands or subdivisions which are upstream. This policy statement is appropriate for the unified drainage ordinance.

The Zoning Ordinance (Section 43-61) establishes the City's policy on setback requirements for construction within flood-prone areas, specifically the Curiosity Creek drainage system. The general policy statement is appropriate for an ordinance but specific identification of lots and parcels is a more appropriately handled through the Drainage Engineering Manual. The seven specific tracts of land described in Section 43-61 should be included in the Drainage Engineering Manual along with the current list of "Red Line" lots in the section delineating flood prone areas.

The Buildings and Building Regulations Ordinance contains three sections which address excavations impacting stormwater, permit review and interagency review coordination, and flood damage control. Section 45-396 permits the excavation, grading, or filling of lands within the City provided that the individual undertaking these activities secures a permit from the City and that the proposed excavation will not adversely affect surface drainage. This policy statement is typical of many ordinances in Florida but is difficult to enforce because the public is generally not aware that fill cannot be placed on private property. This section also contains requirements for side slopes and fencing of drainage retention/detention ponds and is presented in a very confusing fashion. These criteria would be better handled in a Drainage Engineering Manual.

Section 45-400 of the Buildings and Buildings Regulations Ordinance contains the standard provisions for flood damage control mandated by the Federal Insurance Administrator for the National Flooding Insurance Program. This section contains both policy

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and design criteria which have been standarized by the federal government for communities desiring Federal Flood Insurance. As such, both policy statements and design criteria would have to remain in this ordinance. However, the appropriate design criteria should be incorporated in the Drainage Engineering Manual.

The Plumbing Ordinance provides for the regulation of storm drainage plumbing within a building and swimming pool discharges. The direct effect of this regulation on the overall drainage program is probably insignificant but these requirements should be centralized and incorporated in the Drainage Engineering Manual for informational purposes.

## Effectiveness

The effectiveness of the drainage aspects contained in the existing ordinances can be assessed in terms of quantity and quality. The quantity aspects deal with the volume and timing of discharges from individual systems and overall flows from individual basins. In the extreme case, the quantity issue is one of flooding. Water quality issues are new to the field of drainage engineering and, as such, have had very little emphasis in most ordinances to date.

### Quantity Aspects

The drainage sections of existing ordinances have established both policy and design criteria. As urban drainage problems have become better understood in the last decades, city administrators have put in place policies for the design and construction of urban stormwater systems to cope with the rising complexity of the issues and the problems. The interpretation of the objectives and fundamental policies of the drainage sections of existing ordinances by Tampa administrators and staff is consistent with the conceptual approach to drainage program implementation. In this respect, the existing ordinances have been effective in dealing with quantity-based issues.

On the other hand, many of the general policies and broadly stated objectives contained in the drainage sections of the existing ordinances tend to be specific to a number of classic drainage problems. A unified drainage ordinance would serve the City well through reviewing and revising (as necessary) the existing public policy statement and including new policy statements which address the complex drainage problems that have arisen in the last decade and are compatible with the regulatory environment of the 1980's.

## Quality Aspects

With the exception of a vague reference to water quality contained in the Boats, Docks, and Waterways Ordinance (Article II. Pollution of Navigable Waters), the drainage sections of the existing ordinances do not mention water quality. This finding is consistent with most drainage ordinances throughout the state which were drafted prior to the last four or five years. With the evolving environmental concerns of the 1970s and the expanded understanding of non-point and urban runoff, developed in the last decade, more concern has been directed toward stormwater runoff quality. Notable within the regulatory environment is the development of the State of Florida's Stormwater Rule (Chapter 17-25, Florida Administrative Code) which requires the treatment of stormwater discharges.

The majority of the City of Tampa drains to the Hillsborough River both above and below the City water works dam. This receiving water body exhibits substantial water quality problems and rarely meets State water quality standards. The Florida Department of Environmental Regulation has become increasingly concerned with the quality of this water body and the City is presently facing a difficult permitting process for new stormwater outfalls to the river. In line with these developments and in anticipation of a future regulatory approach which will probably be more exacting than current measures, the City should consider adopting certain water quality goals and public policies in a unified drainage ordinance. This document would then effectively state the public policy for dealing with the water quality degradation caused by urban runoff.

## Clarity

In general, the language found in existing ordinances dealing with drainage is clear and concise. A notable exception to this statement is the description of fencing requirements for detention/retention ponds contained in Section 45-396 of the Buildings and Building Regulations ordinance. It is important to remember that drafted sections of the ordinance serve as a policy statement for the public and as such should be clear and concise and written in layman's terms. The existing ordinances for the City have generally achieved this goal.

## SECTION 3

## RECOMMENDATIONS

This chapter contains recommendations based upon the review of the existing ordinances and the cumulative critique. Specifically, recommendations are offered for: 1) additional areas which should be considered for inclusion in the scope of the ordinance; 2) specific recommendations for topical sections which should be included in an urban drainage ordinance; 3) finally, a proposal is presented for adopting a unified drainage ordinance for the City of Tampa. While these comments are targeted at adopting a single drainage ordinance, similar changes could be included in the City Code as additions or modifications to existing sections.

### Additional Scope

The single most important issue with respect to Scope is the adoption of a single ordinance which focuses on establishing objectives and stating policy for drainage within the City of Tampa. A single ordinance would consolidate concepts spread throughout the City Code and present a vehicle for incorporating the acceptable recommendations from this study. Additionally, the City should include water quality considerations in drainage improvements and develop suitable objectives and policy for inclusion in the City Code. Other scope additions necessitated by specific recommendations are described in the following discussion.

### Specific Recommendations

This section provides specific recommendations for topical sections which should be included in an urban drainage ordinance. Generally, these recommendations follow a logical sequence and parallel a model ordinance (Section 4). These recommendations are based on a number of implemented municipal drainage ordinances as well as a number of model ordinances developed by both academic and regulatory groups.

1. A unified drainage ordinance should be designed to compliment and supplement rather than conflict with existing ordinances. The interrelationships between the proposed ordinance and the existing ordinances (Subdivisions, Zoning, Buildings and Building Regulations, and Plumbing) are important and references to these ordinances should be included in any separate drainage

ordinance. Inclusion of this section is consistent with most ordinances reviewed.

2. A section containing definitions should be included in the ordinance to clarify terms and concepts used in the different sections. A more complete definition and discussion (including illustrations and examples as required) of many of these terms and concepts can be provided in the City's Drainage Engineering Manual. Most of the ordinances reviewed included a definitions section.

3. A section containing the detailed objectives of the City's drainage program must be included. A detailed specification of objectives is a necessary part of any drainage program and serves the following important functions:

   - Promotes public understanding of the ordinance objectives and the drainage program.
   - Promotes judicial understanding of the ordinance objectives.
   - Serves as a checklist to determine whether or not the ordinance covers appropriate areas.
   - Outlines the direction and scope of the drainage program.
   - Serves as a means to evaluate the effectiveness of the ordinance and the drainage program.

   Unfortunately, in many of the ordinances reviewed, the objectives were either scattered throughout the ordinance and/or associated publications, or the objectives were not written but were generally understood by the staff implementing the ordinance. Thus, there was no guarantee that these objectives were understood or given careful consideration by the engineers preparing the designs, the municipal staff implementing the ordinance, or the developers. Specific objectives adopted for any aspect of the drainage program should be tailored to fit local conditions and local drainage practice.

4. An essential characteristic for a unified drainage ordinance is recognition of areas which have been subject to flooding or inundation on either a frequent or infrequent basis. These areas, hereafter referred to as

the flood prone lands include, at the minimum, the areas delineated by the 100-year flood plain and the coastal high hazard zone. Additional lands which could be considered for inclusion in this flood prone lands classification are:

- Lands subject to inundation by a 10-year (or lower recurrence interval) storm.
- Wetlands, water courses, floodways, and waterbodies not included in the 100-year flood plain or coastal high hazard zone.
- Isolated topographic depressions with a history of flooding or a high potential for flooding.
- "Red Line" lots identified by City Staff

Some ordinances utilized more than one classification for land subject to flooding and some literature outlining flood plain delineation procedures encourages the use of two or more districts. However, ordinance reviews indicated that multiple designations pose three principal problems: 1) sufficient data is not available to accurately define two or more districts; 2) many jurisdictions do not feel that there is a need for more than one district; and 3) that the use of two or more districts may be harder to administer and causes confusion among engineers and developers. For these reasons, a single classification for flood prone lands (with several type categorizations) is recommended for use in the City's ordinance.

5. The condition of flooding and lands subject to flooding serve a number of important functions in the regional hydrologic cycle/ecological system and should be recognized in the ordinance. These functions include:

   - Flood prone lands provide natural storage and conveyance of flood waters.
   - The water on flooded lands may provide recharge to groundwater and is a basic source of flow to rivers, streams, and estuaries.
   - Temporary storage of surface waters on flood prone lands regulates flood elevations and the timing, velocity, and rate of flood discharges.

- o Flood prone lands maintains water quality by reducing erosion, removing nutrients/pollutants, and retaining sediment.

- o Natural flood prone lands export detritus and other food sources to open water bodies and are a vital habitat for fish, birds, wildlife, and native plant communities.

6. The ordinance should recognize and state that uncontrolled development in flood prone lands is inconsistent with their natural functions. Improper management of flood water has the following significant adverse impacts on the health, safety, and welfare of the community:

   - o The owners of homes and business structures located in frequently flooded areas (including customers, guests, employees, children, and future generations) are subjected to unreasonable risks of personal health, injury and property damage.

   - o Expensive and dangerous search, rescue, and disaster relief operations must be conducted when developed properties are flooded.

   - o Roads and utilities associated with development are subject to damage from flooding at great expense to taxpayers and rate payers.

   - o Flooding of developed properties leads to demand for government to construct expensive and environmentally damaging projects to control flood waters.

   - o Loss of natural water storage capacity leads to reduction in available water supply.

   - o The level, velocity, frequency, and duration of flooding on lands are often increased when flood waters are diverted or displaced.

   - o Water quality is degraded, freshwater inflow to estuaries is disrupted, and habitat is lost.

   - o Property value is lowered and economic activity is disrupted by damaging floods.

7. The appropriate procedures to be followed in the delineating flood prone lands should be included in the

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City's Drainage Engineering Manual. Fortunately, the Federal Insurance Administration has prepared contour maps which delineate the 100-year flood plain in Tampa. The Stormwater Management Division, through citizen input, has been able to identify isolated topographic depressions with a history of flooding or high potential for flooding and has also developed a listing of "red line" lots (lots with small, localized flooding problems). This activity has not been accomplished in a systematic and uniform manner for the entire City and completion of the classification may require a temporary increase in staff. The accumulated collection of information in these federal and city documents is sufficient to provide a basic map delineating these four categories of flood prone lands.

8. A warning and disclaimer of liability should be included as part of the City's ordinance for public and judicial information. Essentially, every area with an urban drainage ordinance has experienced damages from past flooding. The main thrust of the ordinance is to lessen or avoid damages from future floods by limiting development within areas subject to flooding and encouraging existing developments in areas subject to flooding to take steps to minimize flood damage. While a reasonable and conservative basis has been selected for determining the areas to be covered by certain sections of the ordinance, this does not mean that larger floods will not occur or that some other natural or manmade phenomena will not occur that will cause damage to existing developments. Thus, the ordinance is not intended nor should it be construed to imply or assure owners, occupants, or prospective purchasers of property that no flood damage will occur as the result of this ordinance. A determination should be made by the City Attorney after reviewing the proposed ordinance (or ordinance revisions) that this section complies with local, regional (SWFWMD) and state (DER, DNR, FAC) laws and procedures.

9. All of the ordinances reviewed provided some indication of the uses which would be permitted within flood prone lands. Normal uses (those not requiring special use permits) would have to be listed for each category within the flood prone lands classification.

10. The ordinance should provide for special permit uses. This will include land uses which must receive special attention (dependent upon the specific category of flood prone lands) to prevent obstruction of floodways,

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threats to other lands, and substantial damage to the land uses themselves. A determination of the appropriateness of a specific proposed use and the location within the different categories of flood prone lands classification is needed. The important objective of this provision is to provide a procedure by which these uses can be evaluated on a case by case basis. Thus, when the developer desires to use lands within the flood prone zone for uses other than those normally permitted, an application must be submitted which requires detailed engineering studies to document any intended actions. A special permit would be issued only after a public hearing is held by an authorized board (City Council) which determines that the requirements of the ordinance are satisfied. In all cases, technical engineering assistance provided by the Stormwater Management Division should be used to perform the evaluation and advise City Council.

11. In order to assist the City Council in determining the adequacy of a proposed use for a special permit, the ordinance should contain standards for special permit uses. Since the capacity of existing channels and the limits of floods associated with different return periods can be determined, any increase in flood elevation beyond limits of a fixed amount (i.e., 0.1 feet or more) would be prohibited by the ordinance. The allowable increase in flood elevation selected for a specific category within the flood prone lands classification should be related to local conditions and based on good engineering judgment. This approach would be easier to administer and also provides a more definite description of the restrictions to which developers will be subjected.

12. The drainage ordinance should include a section which controls earth movement within lands subject to flooding (and perhaps for all lands throughout the entire City). The goal of this section should be to preserve flow capacity and historic basin storage within individual basins. In addition, fill placed in these areas must be shown to have a beneficial purpose and be protected against erosion. The adverse hydraulic effects of filling and dumping in a basin area located within the flood prone lands classification can be neutralized if compensatory storage is provided and if the design maintains the hydraulic conductivity of the total drainageway, including the flood plain. Compensatory storage seeks to provide artificial flood storage capacity in areas where natural storage capacity has

been lost or reduced as a result of development. Any change in topography has the potential to adversely affect the drainage within a basin. Although the total amount of flood water discharge from a site may not have changed, the water may be diverted from the natural drainage paths and may be concentrated at points where the natural drainage system does not have adequate storage capacity. Any proposed fill should have some beneficial purpose and the filled areas should not be larger than required for that purpose. Filled areas are more suspectible to erosion problems than natural areas and should be protected by appropriate measures.

13. Storage of materials that are bouyant, soluble, flammable, or otherwise injurious when carried by flood waters should be prohibited (where reasonable) by the ordinance for reasons of health and safety. Other materials and equipment can be stored in areas prone to flooding if minimal damage will occur and if the items are anchored or otherwise enclosed to prevent floatation.

14. The unified drainage ordinance proposed for the City should include a section which sets out the procedure for passing upon special use permits for flood prone lands. Emphasis should be placed upon special aspects of this evaluation which supplement usual procedures for evaluating special exceptions, conditional uses, and so forth. This section is important for the following reasons. Zoning, of which flood prone lands regulations are a part, has been critized through the years due to the large number of variances in special use permits granted. There are times when special use permits are justified, but a large number of these permits will tend to dilute the main objectives of the ordinance. For this reason, special use permits should be limited by setting up some definite procedures to be followed in passing on such permits. The specific factors to be considered when a special use permit is evaluated must be defined and some typical conditions delineated.

15. The subject of non-conforming uses is a troublesome and complex area of the zoning law particularly as applied to modifying structures located in flow prone areas. An administrative procedure for handling non-conforming uses would be desirable. The process should permit a case-by-case determination of the probable effects of the change, continuance, or termination of the uses and

must take into account social harm from continued existence and private injury caused by termination. In some cases, special enabling legislation is likely to be needed for such administrative procedures before incorporation into an ordinance. This section of the ordinance, when drafted, should be carefully reviewed by the City Attorney to determine suitability and whether special enabling legislation will be required before implementation.

16. Hydrologic and hydraulic studies form the basis for both the design of proposed drainage systems and improvements as well as the review of these systems. The ordinance should include a section which sets out the general requirements for any hydrologic or hydraulic studies to be used in the permit and/or review process. Each ordinance reviewed had different requirements pertaining to these studies. The primary differences between requirements were associated with geographic location and the importance of these studies as they relate to different sections of a drainage ordinance. These studies should address the rate at which stormwater is generated, the storage provisions on site, and the ultimate disposal off-site. Generally, the larger the system being developed, the larger the impact on the existing drainage system in the City. As the converse is generally also true, the City should establish some criteria for major and minor facilities at which point the requirement for hydrologic and hydraulic studies are unnecessary. Computer simulations are an invaluable tool for evaluating the effects of a proposed development and aid the City and design engineers in preparing and evaluating the necessary engineering studies. Simulation studies are especially helpful in designing and evaluating effects of storage facilities, but the interrelationships between storage facilities cannot be justified for all projects.

17. A section of the ordinance should address the improvements required when land is developed. Hydrologic and hydraulic studies may reveal that the proposed development would cause adverse impacts on upstream and downstream portions of the drainage system. In order to mitigate these impacts, on-site or off-site storage may be required.

18. On-site storage considerations should be identified in the ordinance. Many areas across the country have found on-site storage to be a sound engineering and economical solution to certain drainage problems.

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Through performing an economic analysis, the City of Tampa has shown that a 20% savings can be realized by using retention basins rather than increasing the capacity of the storm sewers to handle the increased runoff. This analysis included costs for land, design, construction, and maintenance, but the retention basins constructed in the City were located within areas having relatively low land prices.

19. Provisions for off-site storage should be included in the ordinance to encourage the use of consolidated storage facilities while still protecting adjacent properties. The City can play a major role in making this option attractive to developers through:

    - Constructing the storage facilities and prorating the cost among the developers benefiting from these improvements.

    - Encouraging developers to cooperate with each other and construct common facilities that will benefit all parties concerned.

20. The unified urban drainage ordinance should define which party shall bear the cost of drainage improvements. The ordinance must clearly state the city's policy for allocating drainage improvement costs. Cost allocations should be based upon the concept that the parties accruing benefits from specific facilities should also be the ones paying for facilities rather than having everyone in the city bear the burden.

    A study of municipal drainage ordinances found that only two municipal ordinances (Tampa and Fairfax County, Virginia) dealt with the costs of drainage improvements. Tampa assessed the developers for needed drainage facilities according to the amount of runoff resulting from their development calculated as a percentage of the total runoff. Tampa's cost sharing system was voluntary but the City personnel reported no major problems obtaining funds from the developers and developers have voiced their approval of the system. Thus, the purpose and intent of this section would be to require developers to pay their portion of the cost for providing reasonable and necessary drainage facilities whether located within or outside the property limits of the land owned or controlled by the developers, but necessitated or required at least impart by their development. Specific criteria for determining developer assessments would be contained in the Drainage Engineering Manual.

21. Erosion and sediment control have profound impacts in urban drainage systems and should be addressed by the ordinance. There are many different erosion and sediment control methods and new ones are continuously being developed. Specific controls can range from retaining natural vegetation in the drainage pathway to the design and construction of sedimentation basins. Rather than including a partial list of typical erosion and sediment control measures in the drainage ordinance, the details, design considerations and criteria, and implementation techniques for these measures should be contained in the City's Drainage Engineering Manual. Thus, the ordinance should emphasize that suitable methods of erosion and sediment control will be required (as needed) to prevent loss of hydraulic capacity and water quality degradation in the urban drainage program.

22. Maintenance of drainage systems by both public and private entities is an important aspect of overall drainage system performance and a section requiring adequate maintenance must be included in the ordinance. If a drainage system is not adequately maintained, the system will not function as designed, flooding may result, and overall effectiveness will be decreased. Municipal experiences also show that when the maintenance responsibility for private systems is left to private owners, little or no maintenance of the drainage system is done. One major problem plaguing many municipal drainage departments is insufficient language in the drainage ordinance requiring drainage system maintenance. Thus, the ordinance must include language which requires both public and private entities to maintain their respective drainage systems.

The ordinance should contain a policy that holds owners liable for proper maintenance and if performed by the City, the owner must pay these costs. Limitations could be included which would indicate that if these systems fail to function properly, cause flooding, or otherwise impact publicly owned and operated systems, the City has police powers to enter the property, and provide necessary maintenance. The necessary frequency and degree of maintenance for private systems should be delineated in the Drainage Engineering Manual. The procedure for initiating maintenance on private property and subsequently collecting the funds expended in that activity should be specified in the ordinance.

23. With regard to subdivisions, the ordinance should require: (1) areas in the subdivision which have been defined as flood prone be appropriately delineated on the subdivision plat; (2) a minimum portion (i.e., 7,000 square feet) of any lot within a subdivision be outside the lands delineated as flood prone and (3) dedication of a drainage easement where the proposed subdivision is traversed by a water course, drainageway, canal, or stream. The details and regulations pertaining to subdividing land are contained in the subdivision regulations (Chapter 35 of the City of Tampa Code). Through placing these requirements in the Drainage Ordinance, the direct relationship with the Subdivision Ordinance will be clarified and the means of administering both ordinances will be strengthened.

24. The City should consider including bond requirements for erosion and sediment control activities for subdivisions and large sites. The City presently requires bonds for public improvements and could expand this practice to include erosion and sediment control maintenance activities. These conditions would provide a cash escrow guarantee to assure the City that emergency flood and erosion control measures could be taken by City Forces at the developer's expense in the event the developer did not initiate specific actions within a time period specified by the Director of Public Works. The City should have the financial means to install necessary control measures to protect other property in the area of the development. This bonding requirement would provide the City leverage to force reluctant developers to install approved flood and erosion control measures without the long and costly legal action normally required.

25. The unified drainage ordinance should be designed to complement and supplement rather than conflict with existing regulations. When regulations on a topic occur in one or more ordinances, the most restrictive regulation should prevail. However, if the City Attorney decides that earlier ordinances should be repeated, a general repeal is not recommended. Instead, the portions and/or sections in conflict with the unified drainage ordinance should be specifically repealed after careful study by the City Attorney for legal content and by the Stormwater Management Division for technical content.

26. The drainage ordinance should have provisions for declaring violations of the ordinance and assessing

penalties. A very effective means of forcing developers to correct violations is an immediate suspension of all development and building permits. This usually does not involve the legal problems associated with prosecuting an offender or trying to collect fines. Erosion and sedimentation violations must be quickly rectified in order to prevent damages that might occur during a long legal conflict.

27. Finally, a mechanism should be included for appeals when an individual is dissatisfied with an act or determination by City Staff in the exercise of the authority granted in the ordinance. This mechanism would probably provide for an appeal for special consideration by the City Council.

# SECTION 4

## MODEL ORDINANCE

A model of a drainage ordinance incorporating the recommendations previously described in Section 3 has been prepared for the City of Tampa. This chapter describes the basis for the development of the unified drainage ordinance and the proposed ordinance is in Appendix A.

Regulating drainage in the City of Tampa is accomplished through subsections in five different ordinances. The City does not have a unified drainage ordinance containing all the necessary provisions for controlling and regulating drainage. For this reason, a model ordinance has been prepared for possible implementation by the city.

The development of a comprehensive urban drainage ordinance for Tampa is not an easy task due to the unique environmental setting and complex drainage problems. Four different sources of information were utilized as the basis for developing the proposed model ordinance and these include:

- Staff interviews -- members in all involved sections of the Department of Public Works were interviewed to secure insight and valid criticism of existing sections from people working with it on a daily basis. Staff members at all levels were interviewed in an attempt to avoid any bias and solicit a wide range of criticisms and suggestions.

- Review studies - urban drainage ordinances and drainage practices were reviewed to determine the nature of ordinance problems in other metropolitan jurisdictions. These studies covered: the Atlanta, Georgia Metropolitan Area (including the City of Atlanta and DeKalb, Fulton, and Clayton counties); Fairfax County, Virginia; Chicago, Illinois; and, Ingham County, Michigan. Interestingly, one study reviewed included a review of the drainage ordinances and review practices for the City of Tampa during the mid 1970's.

- Model ordinances -- a number of model ordinances were reviewed during this task to evaluate and compare the style and contents. The model ordinances were prepared in both academic and regulatory climates and the contrast provides an interesting difference in styles and approaches.

- Review of current municipal ordinances -- ordinances which impact drainage for both large and small municipalities in the state were reviewed to determine differences and similarities in the concerns, organization, and style. Ordinances were reviewed for the Cities of Bradenton, Casselberry, Clearwater, Fort Lauderdale, Jacksonville, Miami, Orlando, St. Petersburg, and Tampa as well as the counties of Duval, Hillsborough, Manatee, Orange, Pinellas, and Seminole.

A skeletal organization for the proposed unified drainage ordinance was provided by a model ordinance prepared by Thomas N. Debo, a drainage engineer working in the metropolitan Atlanta area at the time the model ordinance was developed. Additional language concepts were incorporated from: (1) a model flood management ordinance developed by the Southwest Florida Water Management District; (2) a model ordinance for meeting local water quality management needs developed at the University of Florida Law Center; and (3) numerous city and county ordinances reviewed as part of this work effort.

The final form and content of the proposed unified drainage ordinance has been shaped by the comments and suggestions generated by selected City Staff members reviewing the document. Attempts have been made to make the language and form of the proposed ordinance fit the institutional structure of the City of Tampa and the style of the City Code.

## Proposed Ordinance

Appendix A contains the model unified drainage ordinance prepared for consideration by the City of Tampa. The content and scope of this proposed ordinance take into consideration the critique and review comments reported in the previous sections of the report.

The proposed ordinance is by no means ready for adoption without modification and thorough review. Rather, this proposed ordinance should serve as the basis and pattern for the City in development of a drainage ordinance which meets Tampa's unique municipal requirements and constraints. In other words, this will serve as a beginning point from which to progress.

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# SECTION 5

## DRAINAGE ENGINEERING MANUAL

The Drainage Engineering Manual is the last significant component required to complete Tampa's drainage program. This document is crucial to the success of the program.

- The Manual is highly specific and allows the Council to concentrate on goals and policy statements while the professional engineers and trained technicians concentrate on developing and updating suitable design criteria and analytical procedures.
- The Manual remains flexible since it is not an enacted ordinance which must be subjected to political pressures and compromises in a public forum.
- The Manual is dynamic since it can be revised as necessary by the Department to adjust for short comings, improve system designs and performance, and allow variances for site specific conditions.

The Manual provides the City staff and the community's design professionals a readily useable reference document written in specific, concise technical language which facilitates good design and speeds review by establishing clear design standards, criteria, and policy.

In formulating a drainage program, the drainage ordinance must be written before any accompanying technical or engineering documents are prepared. This allows the latter documents to reflect the technical and engineering requirements needed to administer the ordinance. The following outline and discussion are included to provide a general knowledge of the content and scope of a Drainage Engineering Manual.

This manual would not be adopted into law by the City and would be maintained in a form that could be continually updated and changed to conform to the latest City procedures. The best format for the Drainage Engineering Manual is a loose-leaf notebook that can be easily updated with dated pages. This will be a dynamic rather than static volume and needs to be continually reviewed and updated to stay abreast of developments in the important and rapidly expanding field of urban storm drainage. The Stormwater Management Division will periodically issue revisions to the Manual incorporating new data, methods, criteria, and other information as may be deemed appropriate.

The major thrust of the Manual is to present examples in such detail that a design engineer can determine generally what is expected by the City in different drainage and erosion control designs. The manual should not be a limiting document forcing the engineer to use standard designs and procedures. Several design procedures should be included (and references of additional design criteria and procedures cited) with latitude for the design engineer to use his imagination and sound engineering judgment. In addition, the Manual would provide more complete definitions of the concepts included in the ordinance.

The Department of Public Works, Stormwater Management Division should be entrusted with the responsibility of keeping the Drainage Engineering Manual current. Periodic reviews should be made (i.e., annually or when major changes in the manual occur) by a special committee appointed by City Council. This would enable the elected officials to be kept informed of changes which might affect stated policies and objectives, and also provides a check to ensure a sound basis for a given update. If needed, elected officials or committee members could obtain outside opinions on engineering and technical matters to augment those provided by the Stormwater Management Division.

Following is a preliminary outline of topics to be included in the City's Drainage Engineering Manual. The list is intended to provide a basis for development, not to be all inclusive.

## CITY OF TAMPA

## DRAINAGE ENGINEERING MANUAL

I. AUTHORITY
  1.1 Drainage Ordinance(s)
  1.2 State Law(s)
  1.3 Inter-Agency Cooperation

II. REVIEW PROCESS
  2.1 Review Process Description w/Schematics
  2.2 Review Punch List(s)
  2.3 Construction Completion Certification

III. DRAINAGE POLICY
  3.1 Design Philosophy
  3.2 Minimum Drainage Requirements
  3.3 Comprehensive Design Requirements
  3.4 Cut-Off Criteria for Stormwater Management Plans

3.5 Water Quality Standards
3.6 Minimum Treatment Standards
3.7 Overdrainage/Water Construction
3.8 Loss of Historic Basin Storage Capacity
3.9 Flood Plain Encroachment
3.10 Upstream/Downstream Effects
3.11 Maintenance of Drainage Capacity During Construction
3.12 Building Flood Elevations
3.13 Resolution of Utility Conflicts
3.14 Curbs and Gutters
3.15 Pavement Slope

IV. PLANS, REPORTS AND STUDIES STANDARDS
4.1 Drainage Calculations Reports
4.2 Hydrologic and Hydraulic Investigations
4.3 Plans and Design Drawings
4.4 Standard Work Sheets

V. DESIGN POLICY
5.1 Rainfall Data
5.2 Evapotranspiration
5.3 Antecedent Conditions
5.4 Design Storm(s)
5.5 Time of Concentration
5.6 Runoff
5.7 Off-Site Discharge Regulation
5.8 Pass-Through Drainage Regulation
5.9 Receiving Water Stage
5.10 Percolation
5.11 Infiltration
5.12 Soil Borings
5.13 Storage
5.14 Routing
5.15 Minimum Elevations
5.16 Erosion Control
5.17 Sodding
5.18 Hydroseeding
5.19 Cut-in Seeding

VI. DESIGN CRITERIA
6.1 Drainage Easements
6.2 Access/Maintenance Easements
6.3 Detention/Retention
6.4 Underground Exfiltration
6.5 Swales
6.6 Open Channels
6.7 Pipes
6.8 Discharge Structures
6.9 Control Structures

6.10 Weirs
6.11 Orifices
6.12 Flumes
6.13 Inlets
6.14 Junction Boxes
6.15 Manholes
6.16 Underdrains

VII. DESIGN STANDARDS INDEX

# APPENDIX A

# MODEL DRAINAGE ORDINANCE

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## ARTICLE I. SCOPE

This ordinance amends and supplements the following ordinances:

1. Subdivision Ordinance (Chapter 35, City Code),
2. Zoning Ordinance (Chapter 43, City Code),
3. Building and Building Regulations Ordinance (Chapter 45, City Code),
4. Plumbing Ordinances (Chapter 50, City Code).

## ARTICLE II. DEFINITIONS

For the purpose of this ordinance, the following definitions shall apply:

2.01 Adverse Impacts - Any modifications, alterations or effects on a feature or characteristic of water or flood prone lands including their quality, quantity, hydrodynamics, surface area, species composition, living resources, aesthetics or usefulness for human or natural uses which are or potentially may be harmful or injurious to human health, welfare, safety or property, to biological productivity, diversity, or stability or which unreasonably interfere with the enjoyment of life or property, including outdoor recreation. The term includes secondary and cumulative as well as direct impacts.

2.02 Channel - a natural or artificial wastercourse of perceptible extent, with a definite bed and banks to confine and conduct continuously or periodically flowing water. Channel flows thus is that water which is flowing within the limits of the defined channel.

2.03 Coastal High Hazard Zone - area(s) subject to high velocity waters, including but not limited to, hurricane wave wash, designated on Federal Insurance Rate Maps as Zones VI-30.

2.04 Detention Storage - storm runoff collected and stored for a short period of time and then released at a rate much less than the inflow rate.

2.05 Developer - any person who acts in his own behalf or as the agent of an owner of property and engages in alteration of land or vegetation in preparation for construction activity.

2.06 Development - any action in preparation for construction activity which results in an alteration of either land or vegetation.

2.07 Development Permit - permit issued by the City which is needed before any development operations can be started (including clearing, grubbing, grading, filling, excavation, or any other development operations).

2.08 Drainage - a general term applied to the removal of surface or subsurface water from a given area either by gravity or by pumping, commonly applied herein to surface water.

2.09 Drainage System - the surface and subsurface system for the removal of water from the land, including both the natural elements of streams, marshes, swales and ponds, whether of an intermittent or continuous nature, and man-made elements which include culverts, ditches, channels, storage facilities, and the storm sewer system.

2.10 Elevation - height in feet above mean sea level referenced to the USC&GS (N.O.S.).

2.11 Erosion - the general process whereby soils are moved by flowing surface or subsurface water.

2.12 Flood - a temporary rise in the level of rivers, streams, watercourses, and lakes which results in inundation of areas not ordinarily covered by water.

2.13 100-Year Flood - a flood which has the probability of occurring once every 100 years or having a one (1) percent change of occurring each year.

2.14 Flood Plain - the land adjacent to a body of water which has been or may be covered by flood water including but not limited to the 100-year flood.

2.15 Flood Prone Lands - lands which are subject to being covered by water (1) including the flood plain associated with the 100-year Flood, (2) those lands delineated as the Coastal High Hazard Zone, (3) those lands frequently subjected to inundation by storms with design frequencies of 5-years to 25-years, and (4) those lands identified as "Red Line" lots by the Department of Public Works due to frequent small localized flooding problems.

2.16 Flood-Proofing - a combination of structural provisions, changes, or adjustments to properties and structures subject to flooding primarily for the reduction or elimination of flood damages to properties, water and sanitary facilities, structures, and contents of building.

2.17 Floodway - the normal channel of a watercourse and the adjacent land areas that must remain unobstructed to convey the regulatory flood discharge without raising flood elevations above specified levels as determined in Article IV.

2.18 Hydrologic and Hydraulic Study - engineering study to determine rates, volumes, and distribution of storm runoff.

2.19 Impervious Surface - a surface which has been compacted or convered with a layer of material so that it is highly resistant to infiltration by water. It includes surfaces such as compacted sand, shell material, lime rock, or clay, as well as most conventionally surfaced streets, roofs, sidewalks, parking lots and other similar structures.

2.20 Obstruction - any dam, wall, wharf, embankment, levee, dike, pile, abutment, projection, excavation, channel rectification, bridge, conduit, culvert, building, wire, fence, rock, gravel, refuse, fill, structure, or mater in, along, across, or projecting into any channel, watercourse, or flood plain area which may impede, retard, or change the direction of the flow of water, either in itself or by catching or collecting debris carried by such water, or that is placed where the flow of water might carry the same downstream to the damage of life or property.

2.21 Predeveloped Conditions - those conditions which existed before any individual firm, corporation, government agency, business trust, estate, trust, partnership, association, two or more persons having a joint or common interest, or any other legal entity initiated any construction activity which results in an alteration of land or vegetation.

2.22 **Receiving Bodies of Water** - any water bodies, watercourses or wetlands into which surface water flow either naturally, in man-made ditches, or in a closed conduit system.

2.23 **Red Line Lots** - those lots which experience or may reasonably expected to experience frequent localized flooding problems due to grading related topographic characteristics.

2.24 **Retention Storage** - storm runoff collected and stored with no release after the storm runoff has ended.

2.25 **Sediment** - fine particulate material, whether mineral or organic, that is in suspension or has settled in a water body.

2.26 **Sedimentation** - the processes that operate at or near the surface of the ground to deposit soils, debris, and other materials either on other ground surfaces or in water channels.

2.27 **Storage Facility Study** - engineering study to determine if retention and/or detention storage facilities are needed to control storm runoff from a development.

2.28 **Subdivide** - the division of lands comprising one acre or more into lots, blocks, parcels, tracts or other portions, however designated, so as to comprise three (3) or more such to the acre, or, the division of lands into lots, blocks, parcels, tracts or other portions, however designated, so as to provide for or necessarily require the establishment or extension of streets, alleys, or other rights-of-way.

2.28 **Watercourse** - any natural or artificial channel, ditch, canal, stream, river, creek, waterway or wetland through which water flows in a definite direction, either continuously or intermittently, and which has a definite channel, bed, banks or other discernible boundary.

2.29 **Water Body** - any natural or artificial pond, lake, reservoir or other area which ordinarily or intermittently contains water and which has a discernible shoreline.

2.30 **Watershed** - a drainage area or drainage basin contributing to the flow of water in a receiving body of water.

2.31 Wetland - land that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

## ARTICLE III. STATEMENT OF OBJECTIVES

The following are the adopted objectives of stormwater management for the purposes of this Ordinance.

3.01 Protect human life and health.

3.02 Minimize public and private property damage resulting from erosion, sedimentation, flooding and excessive maintenance requirements.

3.03 Regulate use of flood plains for development, fill, dumping, storage of materials, structures, buildings, utilities, or any other work which acting alone or in combination with other existing or future uses will increase flood heights and velocities, upstream or downstream from proposed use, by obstructing flows and reducing valley storage.

3.04 Regulate development which may, when acting alone or in combination with other developments, create a demand for public investment in flood-control works by requiring protection against flood damage at the time of initial construction and afterwards.

3.05 Ensure, as far as possible, an efficient drainage system that will not result in excessive public or private moneys being used for maintenance and replacement of portions of the system.

3.06 Ensure that the design of the drainage system will be consistent with good engineering practice and design.

3.07 Provide temporary and permanent erosion and sediment control measures to protect individuals occupying land adjacent to and downstream from proposed developments from being damaged by sediment originating from within or because of the proposed development.

3.08 Control flood plain uses to be consistent with approved land use plans for the flood plain areas and coordinated with plans for the total community.

3.09 Provide for development of areas with minimum adverse effects to the natural environment.

3.10 Encourage wise use of the City's economic and fiscal resources.

3.11 Discourage development in areas subject to flooding problems.

3.12 Encourage economical uses and designs in flood plain areas.

3.13 Provide a means of placing potential owners, builders, developers, and the general public on notice of existing and potential flood hazards.

3.14 Utilize existing channel capacity for flood flows before using on-site storage or other structural measures.

3.15 Utilize appropriate public open space for both open space uses (parks, recreational uses, etc.) and the temporary storage of excess storm waters.

3.16 Keep the drainage system as natural and aesthetically pleasing as possible.

3.17 Develop a comprehensive drainage plan for the City to handle storm runoff safely and efficiency.

3.18 Provide for public awareness of the flooding potential.

3.19 Develop interagency relationships with other federal, state, regional, and local governmental units involved in stormwater management in order to solve stormwater problems which cross City boundaries.

## ARTICLE IV. ESTABLISHMENT OF FLOOD PRONE LANDS CLASSIFICATIONS

4.1 Lands to which this Section applies: (1) All of that area inside the 100-year flood contour elevations; (2) All of that area inside the delineated Coastal High Hazard Zone; (3) Lands within the City which are subjected to frequent inundation due to topographic contour characteristics when subjected to storms with

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5-year to 50-year recurrence intervals; and, (4) Red Line Lots.

4.2 Delineation of Flood Prone Lands - The recommended procedures to be followed in order to determine the appropriate elevations of the 100-year flood plain, Coastal High Hazard Zone, and other categories of flood prone lands are outlined and discussed in the City's Drainage Engineering Manual. In addition, this manual lists all approved reports and maps relating to flood prone areas.

4.3 Warning and Disclaimer of Liability - The degree of regulation required by this ordinance is considered to provide a reasonable level of flood protection and is based on engineering and scientific methods of study. Larger floods may occur or flood heights may be increased by man-made or natural causes, such as congested channels and bridge openings constricted by debris. This ordinance does not imply or guarantee that areas outside the delineated flood prone lands or land uses permitted within such a district will be free from flooding or flood damages. This ordinance shall not create liability on the part of the City of Tampa or any officer or employee thereof for any flood damages that result from reliance on this ordinance or any administrative decision lawfully made thereunder.

## ARTICLE V. FLOOD PLAIN DISTRICT USES

5.1 Permitted Uses - Within the flood plain district the following uses are permitted with the exception that none of these uses, when acting alone or in combination with other uses, are to be allowed to affect adversely the capacity of the channels or floodways of any tributary to the main stream and/or the main stream, drainage ditch, or any other drainage facility or system, or in any way affect the free flow of flood waters. This must be documented by appropriate engineering plans and studies as discussed in the City's Drainage Engineering Manual. Specific uses which are not permitted in each of the four categories of the flood prone lands classification are specifically listed in the Drainage Engineering Manual. Determinations of land use suitability will be made by the Stormwater Management Division. The following list of uses is not intended to be all inclusive but only to give typical examples.

5.11 Agricultural uses such as general farming, pasture, grazing, outdoor plant nurseries, horticulture, truck farming, forestry, and wildcrop harvesting.

5.12 Industrial commercial uses such as loading areas, parking areas, airport landing strips, and other nonstructural uses.

5.13 Private and public recreation uses such as golf courses, tennis courts, driving ranges, archery ranges, picnic grounds, swimming areas, parks, wildlife and nature preserves, target ranges, trap and skeet ranges, hunting and fishing areas, bicycle, hiking and horseback riding trails.

5.14 Residential uses such as lawns, gardens, parking areas, play areas, and other nonstructural uses.

5.2 Special Permit Uses - The following uses which involve structures (temporary or permanent), fill, cut, or storage of materials or equipment may be permitted only upon application for a special use permit. Details on such permits are given in Article VI of this ordinance. These uses are also subject to the provisions of Section 5.3 which applies to all flood prone lands special-permit uses. The following list of uses is not intended to be all inclusive:

5.21 Uses or structures accessory to open space or Special Permit Uses.

5.22 Circuses, carnivals and similar transient amusement enterprises.

5.23 Drive-in theaters, road-side stands, signs and billboards.

5.24 Extraction of sand, gravel and other materials.

5.25 Marinas, boat rentals, docks, piers, wharves.

5.26 Railroads, streets, bridges, utility transmission lines and pipe lines.

5.27 Storage yards for equipment, machinery or materials.

5.28 Supports for structures (excluding fill) where the flood level of the structure is above the 100-Year

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Flood Contour Elevation but the supports are within the flood plain area.

5.3 Standards for Flood Prone Lands Special Permit Uses - Following are some minimum standards which all special permit uses must adhere to.

5.31 All Uses - No structure (temporary or permanent), fill deposits (including fill for roads and levees), excavations, obstructions, storage of materials, or equipment, or other use may be allowed as a special-permit use which, acting alone or in combination with existing or future uses, increases flood elevations by 0.1 foot or more beyond the established vertical limits of the delineated flood prone lands district.

5.32 Filling, Dumping, Excavating, and changes in Topography - The following restrictions shall pertain to all filling, dumping, excavation, and changes of topography within the delineated flood prone lands.

(1) No filling or dumping shall be allowed which will increase flood heights beyond the limitations set in Section 5.31 of the ordinance or adversely affect the hydraulic efficiency or capacity of the delineated flood prone lands unless such filling is compensated for by excavation of an equivalent or larger volume in or contiguous to the filled area, and does not adversely affect the hydraulic characteristics of the flood prone lands. The term filling as used here shall mean structures, whether temporary or permanent; obstructions; storage of material; or any other placement of matter in such a manner that may decrease flood plain volume.

(2) No changes in topography (filling or excavation) will be allowed if these changes will result in a concentration of the natural flow of water such as to cause or increase drainage problems. The grading of any area shall be done in a manner to maintain proper drainage throughout.

(3) Any fill proposed to be deposited in delineated flood prone lands must be shown to

have some beneficial development purpose and the amount thereof not greater than is necessary to achieve that purpose, as demonstrated by a plan submitted by the owner showing the uses to which the filled land will be put and the final dimensions of the proposed fill or other materials.

(4) Such fill or other materials shall be protected against erosion as discussed in the City's Drainage Engineering Manual.

5.33 Structures (temporary or permanent) - The following restrictions shall pertain to all structures (temporary or permanent) located within the delineated flood prone lands.

(1) Structures shall not be designed for human habitation unless flood-proofed (as per specifications given in the City's Drainage Engineers Manual).

(2) Structures shall have a low flood-damage potential.

(3) The structure or structures, if permitted, shall be constructed and placed on the building site so as to offer the minimum obstruction to the flow of flood waters.

(4) Structures and all other stored materials shall be anchored or restrained to prevent them from floating away, which may result in damage to other structures, restriction of bridge openings and other narrow sections of the stream or river.

(5) All buildings located within the flood plain district shall be flood-proofed up to an elevation of at least that of the 100-Year Flood Contour Elevation within _____ months after this ordinance is adopted. If the owner chooses not to flood-proof to that level he must file a written statement assuming any flood damages to his structure and contents.

(6) Service facilities such as electrical and heating equipment shall be constructed at or

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above the 100-Year Flood Contour Elevation or flood-proofed.

5.34 Storage of Material and Equipment - The following restrictions shall pertain to the storage of material and equipment within the delineated flood prone lands.

(1) The storage or processing of materials that are in time of flooding buoyant, flammable, explosive, soluble, expansive, or could be injurious to human, animal or plant life is prohibited.

(2) Storage of other material or equipment may be allowed if not subject to major damage by floods, unless owner files a written statement assuming any flood damages to his property, and if firmly anchored, restrained, or enclosed to prevent them from floating away.

5.35 Public Utilities and Facilities - The location, design, elevation and construction of all public utilities and facilities such as sewer, gas, electrical, water systems, streets, bridges, and culverts shall be in such a manner as to minimize or eliminate damage by flooding, flow obstruction, and sewer overflows.

## ARTICLE VI. SPECIAL USE PERMITS

6.1 Application for Special Use Permit - Any use listed in this ordinance as requiring a special use permit may be allowed only upon application and issuance of a special use permit by the City Council (hereafter referred to as the Council).

6.2 Procedure to be Followed by the Council in Passing on Special Use Permits - Upon receiving an application for a special use permit the Council shall, prior to rendering a decision thereon:

(1) Require the applicant to furnish as much of the following information as is necessary for determining the suitability of the particular site for the proposed use:

(a) Plans showing the nature, location, dimensions, and elevation of the lot, existing or proposed structures, fill, excavation, storage of materials, flood-proofing measures and the relationship of the above to the location of the channel and flood plain district.

(b) A typical valley cross-section showing the channel of the stream, elevation of land areas adjoining each side of the channel, cross-sectional areas to be occupied by the proposed development, 100-Year Flood Contour Elevation, and flood prone lands delineation.

(c) Plans showing elevations or contours of the ground; delineated flood prone lands, pertinent structures, fill or storage elevations; size, locations and spatial arrangement of all proposed and existing structures on the site; location and elevations of streets, water supply, sanitary facilities; photographs showing existing land uses and vegetation upstream and downstream, soil types and other pertinent information.

(d) A profile showing the slope of the bottom of the channel or flow line of the stream.

(e) Specifications for building construction and materials, flood-proofing, filling, dredging, grading, channel improvement, storage of materials, water supply, and sanitary facilities.

(2) Transmit a copy of the above information to the Stormwater Management Division for their review and comment.

(3) Based upon the technical evaluation of the Stormwater Management Division, the Council shall determine the specific flood hazard at the site and shall evaluate the suitability of the proposed use in relation to the flood hazard.

6.3 Factors Upon Which the Decision of the Council shall be Based - In passing upon applications for special use permits, the Council shall consider all relevant factors specified in other sections of this ordinance and:

(1) An evaluation to show that the proposed use will not reduce the capacity of the floodway or increase flood heights beyond those allowed in this ordinance.

(2) The danger that materials may be swept into other lands or downstream.

(3) The proposed water supply and sanitation systems and the ability of these systems to prevent disease, contamination, and unsanitary conditions.

(4) The importance to the community of the services provided by the proposed facility.

(5) The requirements of the facility for a waterfront location.

(6) The availability of alternative locations not subject to flooding.

(7) The compatibility of the proposed use with existing development and development anticipated in the near future.

(8) The relationship of the use to the comprehensive plans and flood prone lands management programs for the City.

(9) The safety in times of flood of access of ordinary and emergency vehicles to the property.

(10) The expected heights, velocity, duration, rate of rise, and sediment transport of the flood waters expected at the site (if the Council feels this information is needed).

(11) Such other factors as are relevant to the purpose of this ordinance.

6.4 Time for Acting on Application - The Council shall Act on an application in the manner described within _____ days from receiving the application, except when additional information is required by the Council or the Stormwater Management Division to prepare recommendations. The Council shall render a written decision within _____ days from the receipt of such information.

6.5 Conditions Attached to Special Use Permits - Upon consideration of the factors listed above and the purposes

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of this ordinance, the Council shall request the Stormwater Management Division to prepare specific conditions (as required) for the Permit and may attach such conditions to the granting of special use permits or variances as it deems necessary to further the purposes of this ordinance. Following are some examples of such restrictions:

(1) Modification of waste disposal and water-supply facilities.

(2) Limitations on periods of use and operation.

(3) Imposition of operational controls, sureties and deed restrictions.

(4) Requirements for construction of channel modifications, dikes, levees and other protective measures.

(5) Flood-proofing measures consistent with the standards and specifications for flood-proofing contained in the City's Drainage Engineering Manual.

## ARTICLE VII. NONCONFORMING USES

7.1 A structure or the use of a structure or premises which was lawful before the passage or amendment of this ordinance but which is not in conformity with the provisions of this ordinance may be continued subject to the following conditions:

7.11 No such use shall be expanded, changed, enlarged, or altered in a way which increases its degree of nonconformity.

7.12 No structural alteration, addition or repair to any nonconforming structure shall exceed _____ percent of its value at the time of its becoming a nonconforming use, unless the structure is permanently changed to a conforming use.

7.13 If such use is discontinued for _____ consecutive months, any future use of the building premises shall conform to this ordinance.

7.14 If any nonconforming use or structure is destroyed by any means, including floods, to an extent of __

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percent or more of its value, it shall not be reconstructed except in conformity with the provisions of this ordinance.

7.15 Uses which become nuisances under conditions of prevailing ordinances shall not be entitled to continue as nonconforming uses.

7.16 Except as provided in Section 7.15, any use which has been permitted as a special permit use shall be considered a conforming use.

7.17 Any alteration, addition, or repair to any nonconforming structure which would result in substantially increasing its flood-damage potential is prohibited.

7.18 The City shall prepare a list of those nonconforming uses which have been flood-proofed or otherwise adequately protected in conformity with Section 6.5 (1) - (5). This list shall be presented to the Council which may issue a certificate to the owner stating that as a result of these corrective measures such uses are in conformity with the provisions of this ordinance.

7.19 If the restrictions placed on a particular use change (e.g., lowering of 100-Year Flood Contour Elevation), a certificate will be issued to the owner stating that a result of these measures such use is in conformity with the provisions of this ordinance.

## ARTICLE VIII. HYDROLOGIC AND HYDRAULIC STUDIES

A hydrologic and hydraulic study of the proposed development shall be submitted with each application for a development permit. These studies will be used to establish the delineation of flood prone lands (if this information is not already available) and also to design retention and detention storage facilities to limit the storm runoff from the development to that which can be contained within the delineated flood prone lands. Thus, these studies will be used to evaluate the total effects a development under review may have upon existing and proposed developments and drainage facilities within the development area. As part of these studies, the effects of the 100-Year Flood on proposed and existing drainage facilities should be determined.

In addition, the effects the proposed development will have on existing developments, drainage facilities, and property upstream and downstream from the proposed development must be evaluated. These studies must show that the proposed development will not create or worsen drainage problems upstream or downstream from the proposed development, and that the limits of the delineated flood prone lands will not be exceeded.

If the limits of the flood prone lands would be exceeded by the increased runoff from a proposed development for the 100-Year Flood or if increased runoff from any design flood, up to and including the 100-Year Flood, would create or worsen drainage problems, then an engineering design must be included in the hydrologic and hydraulic study. This design must show how the increased runoff from the proposed site will be controlled or what changes in the drainage system downstream will be made to accommodate this increased runoff so that the limits of the flood plain district will not be exceeded and drainage problems will not be created or worsened.

## ARTICLE IX. IMPROVEMENTS REQUIRED

If the required hydrologic and hydraulic studies reveal that the proposed development would cause increased flood stages so as to increase the flood damages to existing developments or property, or increase flood elevations beyond the vertical limits set for the delineated flood prone lands, then the development permit shall be denied unless one or more of the following requirements are met:

9.1 On-Site Storage - Provide on-site storage for the increased volume of storm water that results from the proposed development, and provide release mechanism to limit the storm runoff from the storage facility to that which would have been expected from the development site under natural or predeveloped conditions for all design floods which have an adverse effect on existing drainage, up to and including the 100-year flood. Limit the 100-year flood runoff peak from the development so that the vertical limits of the flood prone lands are not exceeded.

9.2 Off-Site Storage - Provide or contribute proportional funding for off-site storage facilities that will control storm runoff so that the limits of the flood plain district are not exceeded and upstream and downstream property is not damaged by increased storm runoff. In using off-site storage, an engineering study must be done to show that property located between the proposed development and the storage facilities will not be damaged by increased runoff.

9.3 Improvements of Existing Drainage System - Improve the existing drainage system, without causing damage to upstream and downstream property or increase flood elevations beyond the vertical limits set for the delineated flood prone lands, to safely accommodate the increased runoff from the proposed development. Care must be exercised in utilizing this option so that the natural environment of the existing drainage system is not unduly harmed.

All proposed improvements must be approved by the Stormwater Management Division.

## ARTICLE X. COST OF DRAINAGE IMPROVEMENTS

The following requirements will determine the proportioning of drainage improvement costs resulting from the proposed development.

10.1 If all the proposed drainage improvements are contained within and are solely for the benefit of the proposed development, then the total cost of these improvements will be borne by the developer of the proposed development.

10.2 If some of the proposed drainage improvements are not contained within the proposed development but are necessitated by and accrue benefits solely to the proposed development then the total costs of these improvements will be borne by the developer of the proposed development.

10.3 If off-site drainage improvements are required as the result of more than one development then the costs of these improvements will be proportional among the developers benefited. Computation procedures for prorating the drainage costs will be determined by the Stormwater Management Division.

10.4 If a developer wants to develop a portion of an area draining to a proposed off-site drainage improvement, before this improvement is constructed, he may use either of the following options:

10.4.1 construct the proposed off-site drainage improvement which will serve the entire area draining to this facility, or

10.4.2 provide the funds for the construction of this drainage facility.

This will allow the developer to proceed with the improvements of his land without damaging the properties of others (assuming, if option B is selected, the City constructs the drainage facility before improvements are made). The City will endeavor to collect, on pro-rata basis, any excess funds plus interest expended by this developer beyond his proportionate share of the cost of such improvements from future properties within the watershed served by such drainage improvements when such properties are developed within a period of ten years from the date that the drainage improvements are financed or constructed. These funds plus interest, if collected, will be turned over to the initial developer or his assigns.

10.5 If the City chooses to provide drainage facilities, the cost of these facilities will be prorated and assessed as a development cost when and if development occurs on the affected lands within a ten year period.

## ARTICLE XI. EROSION AND SEDIMENTATION CONTROL

Proposed temporary and permanent erosion and sediment control plans shall be submitted with each application for a development permit. These plans shall specify in detail the erosion and sediment control measures to be used during all phases of clearing, grading, filling, construction, and permanent development and accurately describe their proposed operation. In addition, these plans shall be in accordance with the latest specifications and recommendations as outlined in the City's Drainage Engineering Manual.

No clearing, grading, excavating, filling or otherwise disturbing natural terrain will be permitted until approved City erosion and sediment control measures have been installed except those operations needed to install these measures. All erosion and sediment control measures shall be continuously maintained during the construction phase of the development.

These erosion and sediment control measures shall apply to all features of the construction site, including street and utility installations as well as to the protection of individual lots.

## ARTICLE XII. GRADING AND DRAINAGE PLANS REQUIRED

Grading and drainage plans shall be submitted with each application for a development permit. The results of all hydrologic and hydraulic studies including the 100-Year Flood Contour Elevation and the flood prone lands delineation must be clearly shown on all site plans where applicable. In addition, a soils investigation report to evaluate possible drainage and erosion problems may be required at the option of the Stormwater Management Division were it is felt that unstable slopes or other site conditions warrant such a study.

A detailed discussion of information to be included in the above plans and reports is contained in the City's Drainage Engineering Manual.

## ARTICLE XIII. MAINTENANCE

Any portion of the drainage system, including on-site and off-site storage facilities, that is constructed by the developer will be continuously maintained by the owner or owners subsequent in title of the affected lands unless it is officially accepted by the City Council for City maintenance. In addition, where debris or sediment has accumulated in such a manner as to interfere with the free flow of water or adequate functioning of drainage facilities, the Stormwater Management Division shall require the owner of such properties to clear and remove the debris or obstruction to permit the drainage system to function efficiently.

After notice and reasonable diligent efforts to have the owner of the property remove the debris or obstruction, City Forces are hereby authorized to enter upon such drainageways and clear or remove the debris or obstructions. The cost thereof shall be charged to the owner of the property where said debris and/or obstruction was generated. The City shall not charge such costs to the owners where the debris or obstruction within the drainageway was not generated from his own property or caused by the owner's negligence or action.

If it cannot be determined from what property the debris or obstruction was generated, or if the debris or obstruction was not caused by anyone's negligence or action, then the City will arrange for its removal.

## ARTICLE XIV. SUBDIVISION PLATS

Proposed tentative and final subdivision plats located contiguous to or within the flood plain district shall not be approved except in accord with the following requirements:

14.1 100-Year Flood Contour Elevation - Each plat shall contain a notation clearly stating the 100-Year Flood Contour Elevation as approved and accepted by the Stormwater Management Division. This elevation shall be designated on the plat by a heavy contour line.

14.2 Flood Prone Lands Delineation - Each plat shall contain a notation clearly identifying each of the four categories of the flood prone lands classification where present as determined by the Stormwater Management Division. These areas shall be designated on the plat by suitable shading and contour designation.

14.3 Minimum Lot Area - No lot shall be approved which has less than _____ (7,000 square feet) or _____ percent of the minimum lot area as established by the applicable zoning district regulations above the level of the 100-Year Flood Contour Elevation.

14.4 Drainage Easement - Where a proposed subdivision is transversed by a watercourse, drainageway, canal or stream, appropriate dedication or suitable easement provisions shall be made to accommodate storm water and drainage through and from the proposed subdivision. Said dedication or easement shall conform substantially with the lines of said watercourse and be of sufficient width or construction, or both, as to be adequate for the purpose including access for maintenance. The specific details pertaining to the size and extent of dedications or easements are contained in the City's Drainage Engineering Manual.

## ARTICLE XV. BONDING

The Bonding requirements for subdivision and site plans shall include a cash escrow guarantee which would assure the City that emergency flood and erosion control measures could be taken by the City at the developer's expense if he did not initiate such action within such period as determined by the Stormwater Management Division. The amount of such bond will be determined by the Stormwater Management Division and will be held by the City until all drainage and erosion control measures have been accepted by the City.

## ARTICLE XVI. REPEAL OF CONFLICTING ORDINANCES

The following ordinances or parts thereof are hereby repealed:

## ARTICLE XVII. VIOLATION AND PENALTY

Any person, firm or corporation violating any of the provisions of this ordinance shall be deemed guilty of an offense and upon conviction thereof shall be punished as provided by (cite local law section regarding fine, jail time, or both). Each day's continuance of a violation shall be considered a separate offense. The owner of any lands or parts thereof, where anything in violation of this ordinance shall be placed or shall exist, and any person who may have assisted in the commission of any such violation, shall be guilty of a separate offense.

In any case in which any land is or is proposed to be used in violation of this ordinance or adopted amendment, the City Attorney may, in addition to other remedies provided by law, institute injunction, abatement or any appropriate action or actions to prevent, enjoin, or abate unlawful use. In addition, upon a finding by the Stormwater Management Division that any provisions of this ordinance has been violated, all development and building permits issued to the violator will be suspended until the violation has been corrected to the satisfaction of the Stormwater Management Division.

## ARTICLE XVIII. APPEALS

In case of dissatisfaction with an act or determination in the exercise of the authority granted herein to the City Departments charged with the administration of this ordinance, any person, firm or corporation shall have the right to appeal to the City Council.

## ARTICLE XIX. EFFECTIVE DATE

This ordinance shall be in full force and effect from and after its passage, approval, and publication as provided by law.

# APPENDIX C

# DESIGN CRITERIA

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# SECTION 1

# INTRODUCTION

The objective of this task is to provide input to the City's stormwater management plan on design and sizing criteria for stormwater collection and conveyance systems with emphasis on both quantity and quality considerations. This section of the technical memorandum reviews the stated scope of Task III.3 and summarizes the activities conducted in Phase II which relate directly to design criteria.

## Scope of Work

The scope of work for this task requires the Consultant to develop and provide design criteria for the city to incorporate into the Stormwater Management Plan (SMP). The development of design criteria is based upon the Tampa NURP Study Phase II findings. These consisted of an extensive field data collection program and subsequent analysis of the data collected. Specific criteria will be developed for five areas including:

- Rainfall analysis -- specific design storms are to be selected for use in estimating runoff with consideration of the statistical analysis of storms developed during Task II.2, rainfall data collected during Task II.3, and analysis of rainfall data accomplished during Task II.6. The design rainfall quality criteria should include single and multiple storm events, and must also address long term rainfall sequences.

- Runoff volume calculations -- based on the analysis of Phase II runoff data, criteria should be developed for use with the runoff generation techniques developed in Task II.6 during Phase II. Attention should be focused on the variation in drainage basin size and the criteria established for larger and smaller basins.

- Water quality considerations -- water quality consequences of stormwater management were evaluated during Phase II with emphasis on problem pollutants. Additionally, flushing and loading characteristics of runoff were evaluated and a predictive technique was developed and applied during Phase II. The criteria developed for water quality considerations will be based upon the predictive technique and should consider basin size and variability. The development of these criteria will be coordinated with the desired stormwater load reductions developed in Task III.1 for the City of Tampa.

- Open channels -- the city's existing criteria for designing open channels is based exclusively on hydraulic capacity. These criteria will be reviewed with respect to the findings of Phase II with regard to undercut ditches and swales. Criteria for designing open channels addressing both hydraulic and water quality considerations will be developed based on the results of the Phase II findings.
- Control measures - design criteria will be developed for selected stormwater control measures for both quantity and quality control based on the effectiveness studies conducted during Phase II. The criteria developed will address the design of detention/retention ponds, drainfields/trenches, open bottom inlets, and undercut ditches/swales.

## Phase II Studies

A great deal of time and money was spent during Phase II in the collecting and analyzing field data relating runoff characteristics from basins of varying sizes and land uses, and the hydraulic and water quality behavior of selected stormwater management practices. The field data collection program utilized seven fixed site monitoring stations equipped with continuous recording flow meters which were electrically interfaced to automatic sampling equipment. Four separate rain gage stations provided support for these fixed site stations.

Five of the fixed site stations were utilized to evaluate and characterize stormwater runoff from storms occurring from June 1, 1982 through February 14, 1983. Four of the fixed site stations were also utilized to evaluate the water quality and hydraulic characteristics of inflow and outflow to two inter-connected detention/retention ponds. More than 335 sets of storm characteristics were collected while monitoring the flow at the runoff characterization sites for these storms. Eighty-one storms were sampled for 179 composite and/or discrete water quality samples. Approximately 80 storms were monitored for hydraulic characteristics in the detention/retention pond system at Horizon Park and approximately 200 individual water quality samples were collected for analyzing water quality characteristics of the inflow and the outflow from these ponds.

Subsequent to the field data collection and data reduction, the runoff characterization and stormwater management practice data have been analyzed for two specific and different objectives. Rainfall and storm runoff data from the characterization basins were analyzed to evaluate important components of the rainfall/-runoff process, allow generation of flows and loads under design conditions, and determine the transferability of these data to other portions of the City. The flow data and water quality information collected at the detention/retention pond system was analyzed to determine the ability of this device to attenuate stormwater volume impacts and to treat or otherwise improve the quality of the urban runoff.

The hydraulic and water quality field data collected and reduced during the first portion of Phase II, and subsequently analyzed pursuant to the two stated objectives, provides the basis for developing the design criteria required by this task. The following four sections of this technical memorandum present the design criteria developed for rainfall analysis, runoff volume calculation, water quality considerations, and control measures. Each section addresses specific findings of the Phase II studies, discusses the procedure utilized in the development of the proposed design criteria, and finally, present the developed design criteria.

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# SECTION 2

# RAINFALL ANALYSIS

## Phase II Findings

Available rainfall data was analyzed for selected characteristics as part of the Tampa NURP Study by Metcalf & Eddy, Inc. Twenty-two calendar years of data (1949, 1951, 1959-1974, 1976-1979) were available and were used in the actual analysis of hourly rainfall data.

The mean annual rainfall in Tampa recorded during this period (1949-1980) was 47.09 inches. The mean annual rainfall recorded during 1949 through 1959 was 52.45 inches while that recorded during 1960 through 1982 was 44.52 inches. This large difference is caused by rainfall during the years 1957 through 1960 which was substantially higher than normal. The mean annual rainfall during these four years was 67.64 inches, considerably higher than the long-term mean annual rainfall. The mean annual rainfalls during the years 1961 through 1970 (42.80 inches) and 1971 through 1980 (43.62 inches) were 9 and 7 percent lower, respectively, than the long-term mean. Such variations are normal in the hydrologic process. Records indicate that normally the driest months are April and November with the wettest months being July and August.

A storm event was defined as recorded rainfall preceeded by or separated from other recorded rainfall by at least six hours during which no measureable rainfall was recorded. The six-hour period is the typical runoff response time in Tampa for a storm event. There is some variation in this value depending on basin characteristics such as size, percent imperviousness, and soil conditions. The six-hour value was checked by M&E using data collected in Tampa and found to be realistic.

Storms with a total rainfall less than 0.10 inches were not considered significant since they normally do not contribute any significant runoff. Consequently, storms with less than 0.10 inch rainfall were neglected in the analyzing total rainfall per storm. For the rainfall data analyzed, there were a total of 2,211 storm events with 1,395 events (63.1 percent) having a total rainfall of 0.10 inches or greater. Approximately one-third of the total number of storms, therefore, had a total rainfall less than 0.10 inches. As discussed earlier, storms with such low precipitation typically contribute very little runoff.

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Analysis of storm durations indicates that the majority of storms have durations less than 6 hours and that a large portion of these storms occurs during the summer months, usually in the form of thunderstorms. Conversely, very large duration storms occur primarily in the winter months and are characteristic of long-term frontal activity. Within this categorization, ninety percent of these storms with less than 0.10 inches of rainfall have durations of 1-3 hours. Inclusion of these storms would strongly skew the distribution of storms by hourly duration.

Analysis of total and seasonal distribution of storm peak intensities indicates that most storms have intensities ranging from 0.10 to 0.50 inches/hour and these storms have the same likelihood of occurrence in winter or summer. Storms of high intensity are less common but occur primarily in June through September, indicating thunderstorm activity.

These statistics show that the most common storms are of short duration and high frequency. In the summer months these take the form of short, intense thunderstorms that occur frequently and have the potential to wash off large pollutant loadings.

## Quantity Based Design

As has been the case in most urban cities throughout the United States, storm sewer systems in the City of Tampa have been constructed for the sole purpose of removing ponded stormwater and preventing urban flooding. In order to achieve these objectives and to facilitate the administrative process of reviewing stormwater sewer designs, one or more design storms have been selected in most major municipalities based on statistical analysis of rainfall patterns and selected recurrence intervals.

### Design Storms

A storm event with a 3- or 5-year recurrence interval has been utilized by the City of Tampa as the basis of storm system design until recent years. However, with the increase in urbanization and development within the City of Tampa, the Department of Public Works has adopted a policy wherein a storm with a 25-year recurrence interval has been utilized as the minimum basis for stormwater management system off-site discharge.

Under normal design conditions, the City permits an individual to discharge water from his site based upon the peak flow for the predeveloped condition. The majority of the existing stormwater systems in the City of Tampa were designed prior to the middle 1970's and were designed on the basis of a design storm having either a 3- or 5-year recurrence interval. However, in cases where the outfall is totally unrestricted, the City permits an individual to discharge a peak flow based on undeveloped conditions and the 10-year recurrence interval storm.

Tampa experiences a wet season-dry season climate where approximately 60%-70% of the annual rainfall occurs in approximately 4-5 summer months beginning in late May. During this period, intense but brief afternoon conductive thundershowers are very common. During these periods brief thunderstorms occur every afternoon, groundwater levels are very high resulting in soil column saturation, and pond levels are very high resulting in lowered surface detention capacity; resulting in significant drainage problems for the City.

The most locally accepted source of rainfall data for defining design storms are the rainfall intensity-duration curves prepared by the State of Florida and contained in the Florida Department of Transportation Drainage Manual. Both the City of Tampa and Hillsborough County utilize this storm data, more specifically the Zone 6 rainfall intensity-duration curves. Figure 1 presents the Zone 6 rainfall intensity-duration curves for storms with recurrence intervals of 3, 5, 10, 25, 50, and 100 years.

Metcalf & Eddy, Inc. developed a set of intensity-duration-frequency curves during Task II.2 of the Tampa NURP Study. These curves were developed from local data collected at the Tampa International Airport and present the intensity-duration relationships for storms with 1-, 3-, 6-, and 12-month and 5-, 10, 25-, 50- and 100-year return frequencies. These storms are also presented on Figure 1.

The intensity-duration-frequency curves developed by the Florida Department of Transportation (FDOT) are recommended to be utilized for storm volume determinations on the basis of the following factors:

- These curves are commonly used in the Tampa Bay Region and are well understood by local developers and engineers.
- FDOT curves are somewhat more conservative than the curves developed by M&E since they predict a higher rainfall volume for the same frequency event and this provides the City with additional capacity when the design is based on the FDOT curves.
- FDOT curves are commonly used by other Urban Cities in the State.

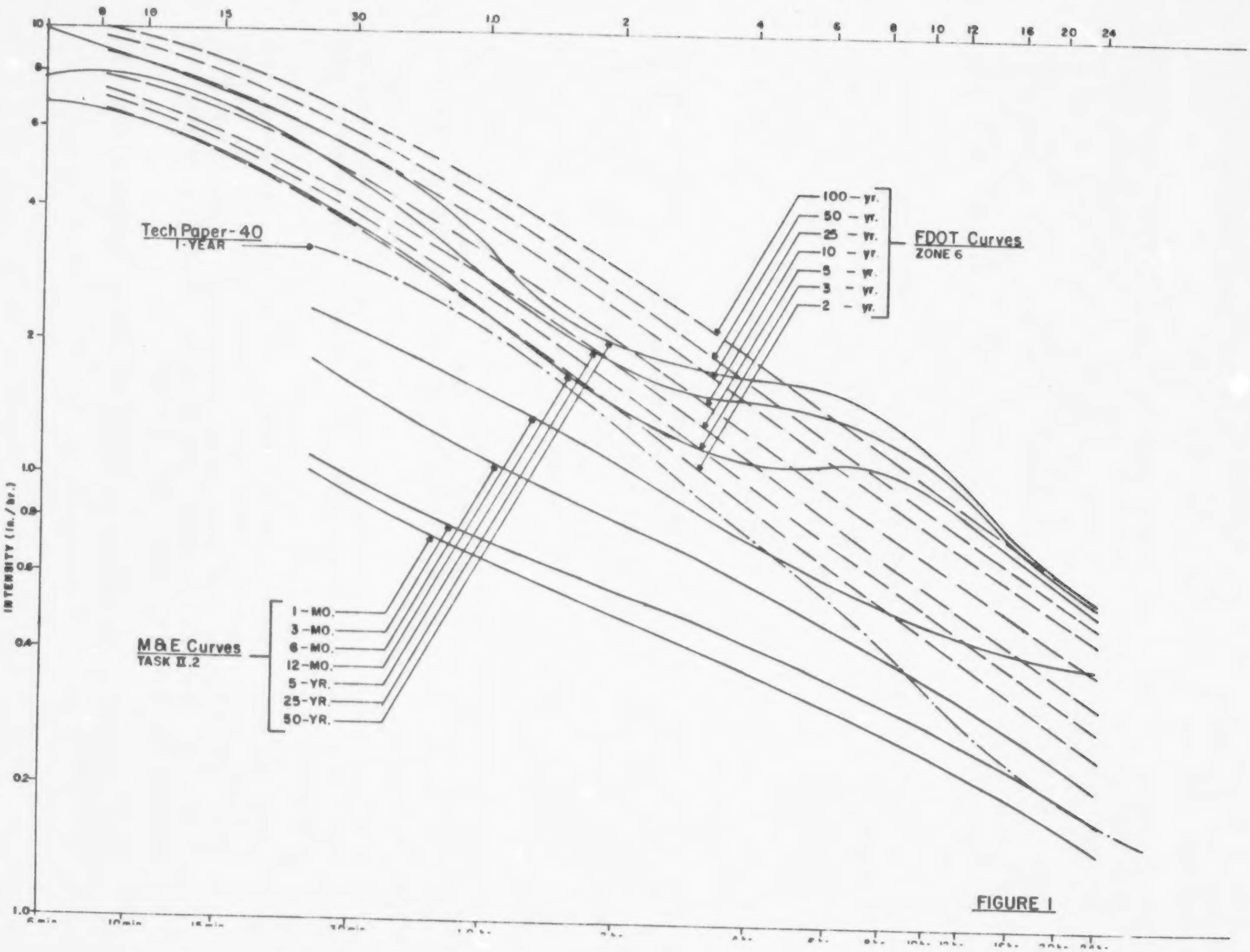

10
8
6
4
2
1.0
0.8
0.6
0.4
0.2
1.0
INTENSITY (in./hr.)
8
10
15
30
1.0
2
4
6
8
10
12
16
20
24
Tech Paper-40
1-YEAR
100-yr.
50-yr.
25-yr.
10-yr.
5-yr.
3-yr.
2-yr.
FDOT Curves
ZONE 6
1-MO.
3-MO.
6-MO.
12-MO.
5-YR.
25-YR.
50-YR.
M&E Curves
TASK II.2

FIGURE I

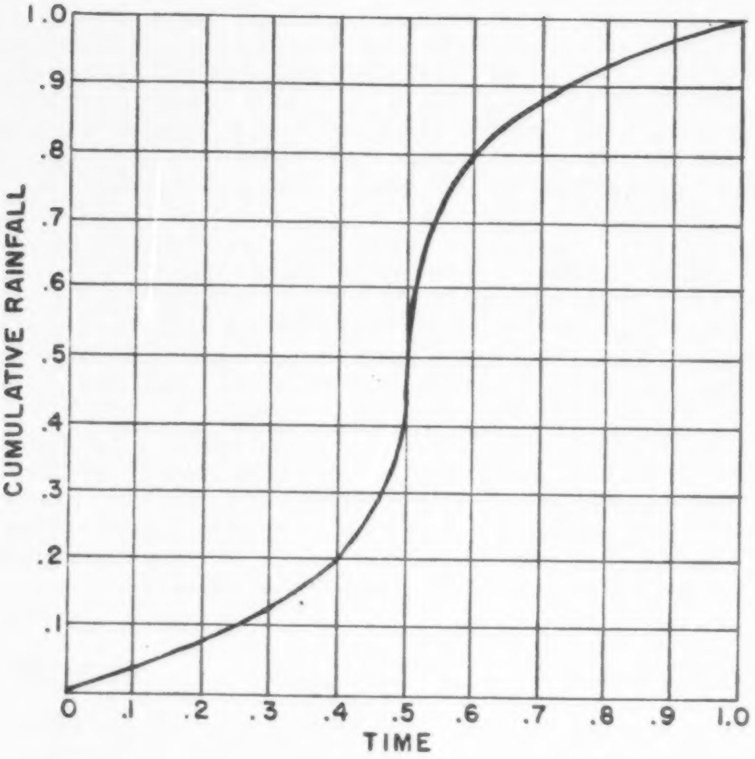
- FDOT curves are required by other agencies in the state that have joint review responsibilities with the City of Tampa on the same projects.

Furthermore, the recommendation is made that the City consider establishing a two-tiered approach to flood protection which is dependent upon land use (arbitrarily called Zone I and Zone II). Zone I land uses would be those generally characterized as low-intensity uses (i.e., as parks, cemeteries, open space, institutional, low-density residential, and neighborhood commercial type activities). Zone II land uses would include those traditionally described as higher intensity (i.e., as high intensity residential, arterial highways, major commercial and central business district). The basis for the differentiation involves two concepts: lower intensity land uses can tolerate ponding better than higher intensity land uses; and the higher intensity land uses require more protection because they are more vital to the health, safety and welfare of the community. The stricter criteria for Zone II land uses address the issue of "acceptable" ponding and provides additional protection for land uses which are more critical to the community. The suggested design basis (peak off-site discharge allowable for three stormwater management systems based on: predeveloped conditions, existing downstream capacity of the conveyance system receiving the off-site discharge, and, a design storm with the stated recurrence interval) for major components of the drainage system for each zone is presented in the following table:

| Component | Zone I | Zone II |
|---|---|---|
| Pipes | 5-year | 10-year |
| Channels | 10-year | 25-year |
| Detention Ponds | 25-year | 50-year |
| Retention Ponds | 50-year | 100-year |

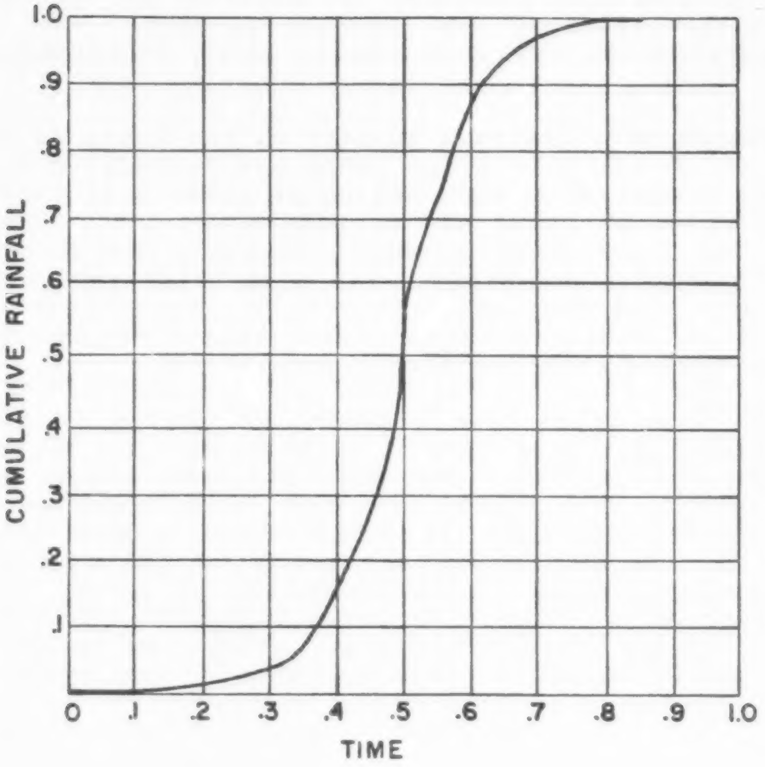
This concept does not require the upgrading of downstream conduits to handle design flows generated by 10-, 25-, 50-, or even 100-year storm peak flows as generated by the rational method. However, it does require that downstream conditions and available conveyance capacities be considered in establishing permissible off-site peak discharge rates and timing. Additionally, this concept provides for a more conservative design basis for critical facilities.

The distribution of rainfall intensity within the storm event has been analyzed for both frequent (1-month to 5-year) and infrequent (10-year to 100-year) storms. Figures 2 and 3 are graphic presentations of the dimensionless hyetographs for low frequency



TAMPA NON-DIMENSIONAL
RAINFALL DISTRIBUTION CURVE
FOR HIGH FREQUENCY STORMS

Figure 2



TAMPA NON-DIMENSIONAL
RAINFALL DISTRIBUTION CURVE
FOR LOW FREQUENCY STORMS

Figure 3

and high frequency storms, respectively, while Table 1 presents the same information in a more usable tabular form.

Metcalf & Eddy, Inc. developed three quantity based design storms which are characteristic of precipitation patterns in Tampa. These storms have frequency/duration characteristics as follow: 5-year/8-hour, 25-year/20-hour and 50-year/24-hour. The event precipitation distribution for each design storm is presented in Table 2.

Multiple event storms were analyzed as part of the Phase II evaluation of rainfall. A multiple storm event was defined to include two or more storm events with each having at least 0.10 inches of rainfall and occurring at least six or more hours after the preceeding event. The 1,395 storm events previously discussed were analyzed for distribution of storms with separation time varying from 6 to 192 hours at 6-hour group intervals. Separation intervals greater than 192 hours contained fewer than 1 percent of all storms and where removed from the sample population.

The most frequent separation time between two storms in the remaining storm population range from 7 to 24 hours with 26% of all storms falling in this range. The most frequent single 6-hour group interval between the storms was the range covering 19-24 hours. This is often the case in Tampa where summer thundershowers occur with some regularity every day in the late afternoon or early evening. A monthly distribution of storms for the three most frequent time separation group intervals (7-12 hours, 13-18 hours, and 19-24 hours) indicates without exception that the highest frequencies occur during June through September. The month of August had the highest monthly distribution for storms in the 7-12 hour and 19-24 hour group. The month of July had the highest distribution for storms spaced 13-18 hours apart. The rainfall depths of these various time separation groups was analyzed in terms of total rainfall depth vs. the probability of occurrence. The intervals for total rainfall from storms separated by 7-12 hours have nearly even distribution when compared to distributions for the 13-18 and 19-24 hour separation time. Storms separated by 7-12 hours have a good probability of accumulating a total rainfall of 2.0 to 4.5 inches indicating that the precipitation event separated by less than half a day may be caused by one large storm system. However, storms separated by longer periods (13-24 hours) are not necessarily part of one storm system.

During the analysis of multiple event storm statistics, a maximum time limit between events had to be selected in order to define storms containing a series of events. Generally, over one-quarter of all rainfall events will occur within 24 hours of each other and this separation time appears to be a natural limit

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## TABLE 1

## DIMENSIONLESS UNIT HYETOGRAPH FOR 24-HOUR DESIGN STORM RAINFALL DISTRIBUTIONS

| | HIGH FREQUENCY STORMS | | LOW FREQUENCY STORMS | |
|---|---|---|---|---|
| Elapsed Time (hours) | Cumulative Rainfall (% Depth) | Incremental Rainfall (% Depth) | Cumulative Rainfall (% Depth) | Incremental Rainfall (% Depth) |
| 0.0 | 0.00 | -- | 0.00 | -- |
| 1.0 | 1.26 | 1.26 | 0.19 | 0.19 |
| 2.0 | 2.57 | 1.31 | 0.39 | 0.20 |
| 3.0 | 3.92 | 1.35 | 0.58 | 0.19 |
| 4.0 | 5.47 | 1.55 | 0.77 | 0.19 |
| 5.0 | 7.00 | 1.53 | 1.38 | 0.61 |
| 6.0 | 9.33 | 2.33 | 2.39 | 1.01 |
| 7.0 | 11.67 | 2.34 | 3.81 | 1.42 |
| 8.0 | 13.06 | 1.39 | 5.83 | 2.02 |
| 9.0 | 17.62 | 4.56 | 10.60 | 4.77 |
| 10.0 | 22.10 | 4.48 | 19.15 | 8.55 |
| 11.0 | 28.67 | 6.57 | 30.48 | 11.52 |
| 12.0 | 50.00 | 21.33 | 50.00 | 19.52 |
| 13.0 | 71.33 | 21.33 | 69.52 | 19.52 |
| 14.0 | 77.90 | 6.57 | 80.85 | 11.52 |
| 15.0 | 82.38 | 4.48 | 89.40 | 3.55 |
| 16.0 | 86.94 | 4.59 | 94.17 | 4.77 |
| 17.0 | 88.33 | 1.39 | 96.19 | 2.02 |
| 18.0 | 90.68 | 2.35 | 97.16 | 1.42 |
| 19.0 | 93.00 | 2.33 | 98.62 | 1.01 |
| 20.0 | 94.53 | 1.53 | 99.23 | 0.61 |
| 21.0 | 96.08 | 1.55 | 99.42 | 0.19 |
| 22.0 | 97.43 | 1.35 | 99.61 | 0.20 |
| 23.0 | 98.74 | 1.31 | 99.81 | 0.19 |
| 24.0 | 100.00 | 1.26 | 100.00 | 0.19 |

---

NOTES:

1. High Frequency = 1-, 3-, 6-, and 12 month and 2-year events.
2. Low Frequency = Those events with 5-year frequencies and higher.

## TABLE 2

## SUMMARY OF QUANTITY BASED DESIGN STORMS

## PRECIPITATION CHARACTERISTICS

| | CUMULATIVE PRECIPITATION FOR STATED STORM | | |
|---|---|---|---|
| Elapsed Time (Hrs) | 5-Year/ 8-Hour (in.) | 25-Year/ 20-Hour (in.) | 50-Year/ 24-Hour (in.) |
| 0.0 | 0.00 | 0.00 | 0.00 |
| 1.0 | 0.70 | 0.09 | 0.02 |
| 2.0 | 1.52 | 0.18 | 0.05 |
| 3.0 | 2.53 | 0.26 | 0.08 |
| 4.0 | 4.15 | 0.35 | 0.10 |
| 5.0 | 5.78 | 0.44 | 0.17 |
| 6.0 | 6.78 | 0.98 | 0.30 |
| 7.0 | 7.54 | 1.70 | 0.47 |
| 8.0 | 8.30 | 2.70 | 0.72 |
| 9.0 | -- | 3.95 | 1.31 |
| 10.0 | -- | 6.08 | 2.37 |
| 11.0 | -- | 8.20 | 3.77 |
| 12.0 | -- | 9.45 | 6.18 |
| 13.0 | -- | 10.45 | 8.58 |
| 14.0 | -- | 11.18 | 9.99 |
| 15.0 | -- | 11.60 | 11.04 |
| 16.0 | -- | 11.80 | 11.63 |
| 17.0 | -- | 11.90 | 11.88 |
| 18.0 | -- | 12.0 | 12.06 |
| 19.0 | -- | 12.1 | 12.18 |
| 20.0 | -- | 12.15 | 12.26 |
| 21.0 | -- | -- | 12.29 |
| 22.0 | -- | -- | 12.31 |
| 23.0 | -- | -- | 12.33 |
| 24.0 | -- | -- | 12.35 |
| TOTAL DEPTH | 8.30 | 12.15 | 12.35 |

to defining historical storms from multiple events. However, an arbitrary separation time of 36 hours was first selected for defining multiple events and determining statistics. The most numerous multiple event storms contain 2 events separated by an average time of 18 hours and the average rainfall for such storms is 1.50 inches though the range of total precipitation is quite large. Table 2 presents the statistics for the 277 multiple event storms having a separation time of 36 hours and more than one occurrence.

The State of Florida requires that stormwater controls to be designed for a maximum detention time of 72 hours (i.e., detention ponds must bleed down in 72 hours from the onset of the rainfall event). In considering this factor, the maximum separation time between events was doubled from 36 to 72 hours and the multiple event storm statistics were recalculated. Again, the most frequent multiple storm event had two storms with an average total rainfall of 1.43 inches and an average separation time of 33 hours. Table 3 presents the statistics for the 313 multiple event storms which have a maximum separation time of 72 hours and more than one occurrence.

Data presented in Tables 3 and 4 indicate that the most frequent storm, a 2-event storm, has a probability of occurrence of about 12 percent. A 3-event storm has an occurrence probability of 5 percent, a 4-event storm has a 2 percent chance of occurrence and a 5-event storm has a 1 percent probability. Obviously, storms with 6 or more events are very rare but can result in heavy precipitation volumes.

Based upon the increasing use of detention/retention ponds in Tampa by both private and municipal entities and coupled these with storm drainage systems, a volume sensitive system having the potential for creating severe flooding problems under wet season conditions can be created. Specifically, if a new storm sewer system is being designed on the basis of a single storm event with a 72-hour bleed down and a controlled retention pond discharge (including an emergency pop-off provision), the designer normally assumes the storm occurs for a maximum of 24 hours and that no precipitation occurs during the next 48 hours while the pond bleeds down. Based on this assumption, pipes, channels, and retention ponds are sized accordingly. However, if one assumes that the 72 hour period occurs during the wet season when groundwater levels are high, the base flow and existing drainage systems discharges are at an elevated level, and these conditions are combined with a 3-day storm event sequence, the bleed down consideration for the pond are different. Under this scenario, the pond may already be partially full since the bleed down process from a previous storm event is still occurring. This scenario is equally valid for systems which have their off-site

## TABLE 3

### MULTIPLE EVENT STORM STATISTICS FOR A MAXIMUM SEPARATION TIME OF 36 HOURS

| No of Storms in Event | Percent of All Storms | No of Events | Average Separation Time (hrs) | Range of Total Rainfall (in) | Average Total Rainfall (in) |
|---|---|---|---|---|---|
| 4 | 66% | 182 | 18 | 0.27 - 7.12 | 1.50 |
| 3 | 21% | 57 | 19 | 0.53 - 12.98 | 2.28 |
| 4 | 8% | 22 | 18 | 0.81 - 10.39 | 3.06 |
| 5 | 5% | 14 | 20 | 1.09 - 18.25 | 5.55 |
| 6 | 1% | 2 | 20 | 2.83 - 3.03 | 2.93 |

## TABLE 4

### MULTIPLE EVENT STORM STATISTICS FOR A MAXIMUM SEPARATION TIME OF 72 HOURS

| No of Storms in Event | Percent of All Storms | No of Events | Average Separation Time (hrs) | Range of Total Rainfall (in) | Average Total Rainfall (in) |
|---|---|---|---|---|---|
| 2 | 51% | 160 | 33 | 0.27 - 7.12 | 1.43 |
| 3 | 21% | 67 | 33 | 0.43 - 9.35 | 2.20 |
| 4 | 10% | 32 | 30 | 0.93 - 10.39 | 3.33 |
| 5 | 5% | 16 | 28 | 1.09 - 6.26 | 3.32 |
| 6 | 3% | 10 | 32 | 2.08 - 8.57 | 4.32 |
| 7 | 4% | 13 | 30 | 1.63 - 19.63 | 5.87 |
| 8 | 3% | 9 | 31 | 1.81 - 7.08 | 4.50 |
| 9 | 1% | 4 | 30 | 5.19 - 7.79 | 6.93 |
| 10 | 1% | 2 | 39 | 6.89 - 9.70 | 8.30 |

discharge rate limited by downstream conditions and/or predevelopment runoff rates and must bleed down over a longer period (say 48 hours).

Additionally, the flow condition in the storm drainage system is somewhat elevated due to the wet conditions and the continual drainage in the basin. Further, a 3 event storm sequence may not ever reach the peak design discharge for the pond which was based on a 24-hour, 10-year event. On the other hand, the second day's rainfall would be very intense and may cause the already wet pond to pop-off at a much higher rate than was anticipated by the designer. Under these conditions, a critical multiple event such as a 4- 5- or 6-event storm can be selected and used for a drainage design for critical systems. Under such conditions, multiple event storms are likely to produce worse flooding conditions than 1 large design storm because there may not be sufficient time for draining the detention basins before peak runoff from subsequent events occur.

## Quality Based Design

An alternative approach to designing storm sewer systems for flood prevention is to design stormwater management systems to mitigate and reduce water quality impacts on the receiving water. Tampa has sponsored the Receiving Water Study in the Lower Hillsborough River as an augment to the Tampa NURP Study. The goal of the Receiving Water Study was to develop a high-speed digital computer model which accurately simulates observed hydraulic and water quality characteristics in the Lower Hillsborough River and then to use this model in the analysis of impacts upon the receiving water due to urban runoff. Consequently, a series of storms with varying recurrence intervals, duration, and precipitation amounts can be analyzed in order to determine the relative impacts on the receiving water. A "water quality design storm(s)" can be designated based on the findings of these studies.

### Design Storm

The designation of a water quality design storm is based upon the findings of Tasks II.6, III.1, III.4, and the Receiving Water Study. While the majority of engineers are familiar with runoff quantity design storms, the concept of a water quality design storm is relatively new. Essentially, this storm is a threshold storm which is characterized by relatively low frequency (less than one year recurrence interval) and a relatively small runoff volume. During periods of drier weather when pollutant accumulation on land surface is high, a small storm event can have a particularly pronounced impact on the receiving waters due to the relatively high pollutant concentrations resulting from long term pollutant accumulation and a small runoff volume. The designation of a water quality design storm for the City of Tampa is based upon the Lower Hillsborough River as the receiving water.

The storm event which has been designated as the water quality design storm is a 1-month, 2-hour storm with a total rainfall depth of 0.96 inches. The distribution of rainfall intensities and volumes within this storm is depicted graphically by the hyetograph presented in Figure 4 and summarized in Table 5. The interesting characteristics of this storm include:

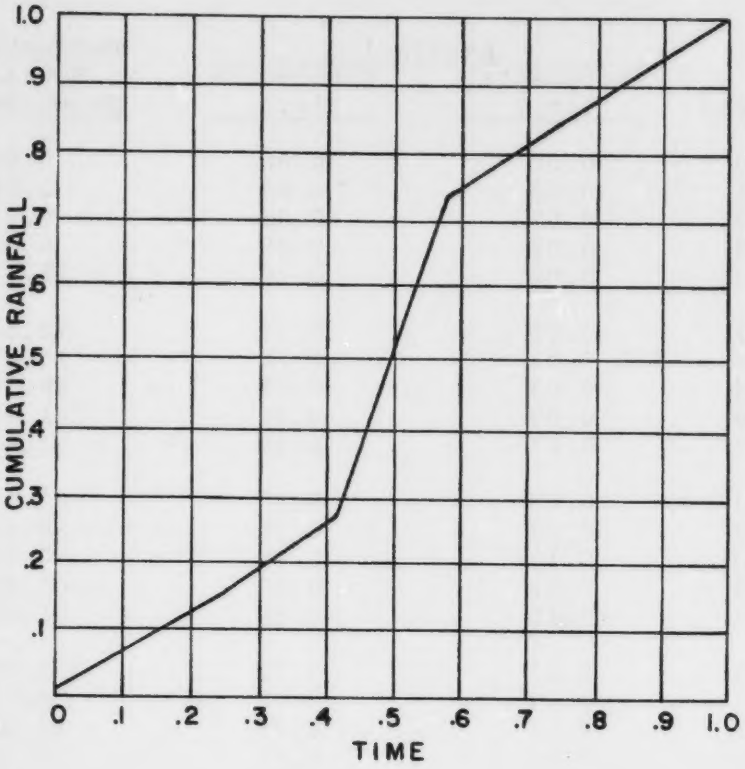
- o The duration matches the highest time frequency (2 hours) determined for Tampa rainfall which is also characteristic of summer thunderstorms.
- o The volume is very close to the FDER requirement for retention of the first inch of rainfall on-site.

## Storm Loads

The results from the Task II.3 analysis of precipitation quality indicates that the total load of pollutants in the stormwater runoff consists of an identifiable pollutant load associated with the precipitation in addition to the pollutants which are washed off the land surface. The Task II.3 report summarizes the characteristics of the bulk precipitation samples collected and described the sampling effort utilized in wetfall/dryfall differentiation.

A conservative estimate of the component of the runoff pollutant load attributable to precipitation quality can be developed through utilizing the average concentrations which have been monitored for bulk precipitation samples in the Tampa NURP study. Knowing the average concentration and the basin size provides the ability to estimate total precipitation load. Table 6 presents the estimated unit precipitation pollutant loads for Tampa based on the monitored precipitation quality. The table presents the mean concentrations determined and the precipitation load along with the estimated load per acre per inch of rainfall for basins having runoff coefficients (Rc) of 0.50, 0.70, and 0.90.

96<



RAINFALL DISTRIBUTION CURVE
FOR WATER QUALITY DESIGN STORM

Figure 4

## TABLE 5

## WATER QUALITY BASED DESIGN STORM

## PRECIPITATION CHARACTERISTICS

| Elapsed Time | | Rainfall | | Percent of |
|---|---|---|---|---|
| (minutes) | (hours) | Incremental (in.) | Cumulative (in.) | Total Storm Depth |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.08 | 0.02 | 0.02 | 2.08 |
| 10 | 0.17 | 0.03 | 0.05 | 5.21 |
| 15 | 0.25 | 0.03 | 0.08 | 8.33 |
| 20 | 0.33 | 0.02 | 0.10 | 10.42 |
| 25 | 0.42 | 0.02 | 0.12 | 12.50 |
| 30 | 0.50 | 0.03 | 0.15 | 15.63 |
| 35 | 0.58 | 0.03 | 0.18 | 18.75 |
| 40 | 0.66 | 0.03 | 0.21 | 21.98 |
| 45 | 0.75 | 0.03 | 0.24 | 25.00 |
| 50 | 0.83 | 0.03 | 0.27 | 28.13 |
| 55 | 0.92 | 0.10 | 0.37 | 38.54 |
| 60 | 1.00 | 0.11 | 0.48 | 50.00 |
| 65 | 1.08 | 0.11 | 0.59 | 61.46 |
| 70 | 1.17 | 0.10 | 0.69 | 71.88 |
| 75 | 1.25 | 0.03 | 0.72 | 75.00 |
| 80 | 1.33 | 0.03 | 0.75 | 78.13 |
| 85 | 1.42 | 0.03 | 0.78 | 81.25 |
| 90 | 1.50 | 0.03 | 0.81 | 84.38 |
| 95 | 1.58 | 0.03 | 0.84 | 87.50 |
| 100 | 1.66 | 0.02 | 0.86 | 89.58 |
| 105 | 1.75 | 0.03 | 0.89 | 92.71 |
| 110 | 1.83 | 0.02 | 0.91 | 94.79 |
| 115 | 1.92 | 0.03 | 0.94 | 97.92 |
| 120 | 2.00 | 0.02 | 0.96 | 100.00 |

## TABLE 6

## ESTIMATED PRECIPITATION UNIT POLLUTANT LOADS FOR TAMPA

| Parameter | Mean Concentration (mg/l) | Precipitation Load (lbs/ac.in.) | Estimated Loads | | |
|---|---|---|---|---|---|
| | | | Rc=0.50 (lbs/ac-in) | Rc=0.70 (lbs/ac-in) | Rc=0.90 (lbs/ac-in) |
| BOD | 3 | 0.68 | 0.34 | 0.48 | 0.61 |
| COD | 17 | 3.85 | 1.92 | 2.69 | 3.46 |
| TSS | 6 | 1.35 | 0.68 | 0.95 | 1.22 |
| O-Phosphorus | 0.10 | 0.023 | 0.011 | 0.016 | 0.020 |
| T-Phosphorus | 0.16 | 0.036 | 0.018 | 0.025 | 0.033 |
| Nitrate | 0.24 | 0.054 | 0.027 | 0.038 | 0.049 |
| Nitrite | 0.007 | 0.002 | 0.001 | 0.001 | 0.001 |
| TKN | 0.45 | 0.102 | 0.051 | 0.071 | 0.092 |
| Ammonia Nitrogen | 0.11 | 0.025 | 0.012 | 0.017 | 0.022 |
| Organic Nitrogen | 0.42 | 0.095 | 0.048 | 0.067 | 0.086 |
| Total Nitrogen | 0.83 | 0.188 | 0.094 | 0.132 | 0.169 |
| Cadmium | 0.0009 | 0.00020 | 0.00010 | 0.00014 | 0.00018 |
| Copper | 0.035 | 0.0079 | 0.0039 | 0.0056 | 0.0071 |
| Lead | 0.0062 | 0.0014 | 0.0007 | 0.0010 | 0.0013 |
| Zinc | 0.146 | 0.0331 | 0.0165 | 0.0231 | 0.0298 |
| Chromium | 0.0037 | 0.00080 | 0.00042 | 0.00059 | 0.00075 |
| Iron | 0.027 | 0.0061 | 0.0031 | 0.0043 | 0.0055 |
| Manganese | 0.0045 | 0.00102 | 0.00051 | 0.00071 | 0.00092 |
| Nickel | 0.0023 | 0.00052 | 0.00026 | 0.00036 | 0.00047 |

## SECTION 3

## RUNOFF VOLUME CALCULATION

This section describes various ways for calculating the runoff volume associated with an individual storm event or a series of storm events. Initially, the discussion centers around the methodology developed for use in analyzing the NURP Phase II field data. A single event model was selected to analyze events for discrete sampling data and a simplified rainfall runoff model was used to evaluate composite-sampled events. The last portion of this section discusses alternate methodologies for calculating runoff volume including the Rational Method, SCS methods, and USGS regression equations.

### Phase II Findings

Runoff volume data collected in each of the five characterization basins during Phase II was analyzed to determine the hydraulic runoff characteristics. The SWMM model was the primary tool utilized to analyze the hydraulic data and to describe variability within individual runoff events. In order to identify important factors in the rainfall-runoff process in Tampa, the SWMM model was calibrated and verified for each of the five basins.

The SWMM model represents the complex time-varying physical processes for accumulating pollutants on the surface, washing pollutants off during storm events, and transporting pollutants through the storm sewer system. These processes were simulated by the SWMM model to predict both hydraulic runoff characteristics and water quality characteristics for the individual basins.

SWMM was found suitable for the simulation of rainfall-runoff characteristics. Through the calibration and verification process, the following factors were determined to have an important influence upon runoff generation: rainfall; basin and transport characteristics; ditch systems; in-system storage; and, infiltration. The unexpectedly high infiltration rates observed in ditches and their in-system storage created difficult problems in the modelling process. However, SWMM provides a reasonable simulation of total event volume and variability within the storm.

### Design Project Size Criteria

When a stormwater management system is designed, the size of the drainage project has an effect on both the physical size of components as well as the methods utilized in the analyzing the site and preparing the drainage calculations. Many techniques exist today for analyzing stormwater flows ranging from a simple rule of thumb to complex computer models and the choice of an appropriate methodology will have a significant impact on the reliability and the quality of the results. The purpose of this section is to establish appropriate criteria for use with different runoff generation methodologies based upon drainage project size.

## Tampa NURP Runoff Prediction Method

The method chosen to predict stormwater runoff characteristics in Tampa was the SWMM model. This model is one of the most comprehensive models for design and evaluation of stormwater systems available today. The individual simulation blocks and the method of application has been described in detail in the Task II.6 runoff characterization and data analysis report. The remainder of this section will address the use and application of these modelling efforts in the analyzing stormwater systems for Tampa.

The input data required in the SWMM model are of two basic types -- storm sewer system data and subcatchment area data. Sewer system data consists of all the physical parameters associated with the system while subcatchment data are the various characteristics contained in the drainage basin. Sewer system data requirements for conduits are:

- Length of individual conduits between nonconduit sewer elements (in feet).
- Invert slope of conduit (feet per hundred feet).
- Manning's n roughness coefficient for the conduit.
- Diameter of the conduit in feet.

If the conduit is not circular, those characteristics must be described in the model. If infiltration into the system is to be estimated, several factors must be determined. The three types of infiltration that can occur are: (1) dry weather infiltration; (2) groundwater infiltration; and, (3) rainwater infiltration. In order to simulate infiltration, estimates must be prepared for each type of infiltration for the total sewer. These data can be from previous flow records or generalized estimates based on similar systems in other areas.

Subcatchment area data consist of various physical parameters describing the drainage basin. The particular drainage basin is subdivided into individual catchments for the model simulation. Subcatchments represent idealized runoff areas with uniform slopes. Dividing the drainage basin into subcatchments can be done by using various parameters i.e., land use, topography and roughness. This subdivision can be carried to as small a catchment as desired. The data required for the subcatchments include:

- Width of the subcatchment
- Area of the subcatchment (in acres)
- Percent impervious of the subcatchment
- Ground slope (in feet per feet)
- Manning's n for the impervious area
- Manning's n for the pervious area
- Retention storage for the impervious area (inches)
- Retention storage for the pervious area (inches)
- Maximum infiltration rate (inches per hour)
- Minimum infiltration rate (inches per hour)
- The k rate of infiltration (liters per second)

A significant finding of the modelling for the Tampa NURP study was that some of the basin characteristics in Tampa are significantly different from those assumed in the default parameters for the SWMM model. EPA's publications on the model SWMM describe each individual block used in the model runs in great detail and provide default values for use when specific values are unknown. These documents describe the basis of the model development, present detailed instructions for the use of the model, and provide example runs. As an assistance for individuals using the SWMM model in Tampa, selected subcatchment characteristics are presented in Table 7 for the five runoff characterization basins in the Tampa NURP study and the SWMM default values are also provided for comparison purposes. This variable listing is provided in lieu of design criteria. Users can compare the basin(s) which they are modelling with the characteristics of the five NURP basins as a basis for selecting subcatchment characteristic values.

$$Q = CIA$$

where

$Q$ = stormwater runoff (cubic feet per second)

$C$ = the coefficient of runoff (dimensionless number)

$I$ = the intensity of rainfall (inches per hour)

$A$ = drainage area (acres)

The runoff coefficient, C, is a variable in the Rational Method which is least susceptible to a precise determination and provides the designer with a degree of independent judgment. The runoff coefficient accounts for extractions (losses between rainfall and runoff) which may vary with time for a given drainage area. These losses are caused by interception by vegetation, infiltration into permeable soils, retention in surface depressions, and evaporation and transpiration. Table 7 summarizes allowable runoff coefficients and is divided into two groups based upon common descriptions of the area and the character of the surface. In determining appropriate runoff coefficients for drainage calculations, differing climatalogical and seasonal conditions, antecedent moisture conditions, and the intensity and frequency of design storm should be considered.

Generally, when storms of a more severe nature or higher recurrence interval occur, the runoff from a given parcel of land increases due to saturation of land surfaces and changes in the characteristics of the basin during the storm. The Rational Method can compensate for this phenomena by a slightly modifying the formula:

$$Q = C_f CIA$$

where $C_f$ represents a correction factor for higher intensity events. The runoff coefficients presented in Table 8 were developed for a storm with a recurrence interval of 2 to 10 years. The appropriate correction factors for storms with higher recurrence intervals are summarized in the following table:

| Recurrence Interval (Years) | Correction Factor |
|---|---|
| 2-10 years | 1.00 |
| 25 years | 1.10 |
| 50 years | 1.20 |
| 100 years | 1.25 |

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Source: Omaha Stormwater Design Manual

## TABLE 7

## INPUT PARAMETER VALUE RANGE MATRIX FOR TAMPA BASINS FOR SWMM HYDRAULIC MODEL

| Subcatchment Characteristics | SWMM Default | J.L. Young Apartments | Wilder Ditch | North Jesuit | Charter & Harding | Norma Park |
|---|---|---|---|---|---|---|
| Number of Subcatchments | -- | 13 | 10 | 4 | 7 | 7 |
| Width (feet) | -- | 112-580 | 540-2530 | 188-450 | 350-966 | 330-2950 |
| Area (acres) | -- | ≤1.0 | 12-32 | 5-12 | 5-8 | 3-10 |
| Imperviousness (%) | 0.001 | 5-90 | 5-85 | 20-35 | 5-15 | 75-98 |
| Ground Slope (feet/feet) | 0.030 | 0.007-0.048 | 0.001-0.004 | 0.006 | 0.005-0.008 | 0.001-0.005 |
| Manning's n-Value: | | | | | | |
| Pervious Areas | 0.013 | 0.013 | 0.013 | 0.013 | 0.013 | 0.013 |
| Impervious Areas | 0.250 | 0.250 | 0.250 | 0.250 | 0.250 | 0.025 |
| Retention Storage (inches): | | | | | | |
| Pervious Areas | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| Impervious Areas | 0.184 | 0.250 | 0.184 | 0.250 | 0.250 | 3.000 |
| Infiltration Rate (inches/hour): | 3.00 | | | | | |
| Maximum | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Minimum | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |
| Infiltration Decay Rate (liters/second) | 0.00115 | 0.00115 | 0.00115 | 0.00115 | 0.00115 | 0.00115 |

## TABLE 8

## ACCEPTABLE RUNOFF COEFFICIENTS

| Area Classifications: | Runoff Coefficient |
|---|---|
| Business | |
| Downtown | 0.70 to 0.95 |
| Neighborhood | 0.60 to 0.90 |
| Residential | |
| Low Intensity | 0.40 to 0.50 |
| Low-Medium Intensity | 0.45 to 0.70 |
| Medium Intensity | 0.50 to 0.75 |
| High Intensity | 0.60 to 0.90 |
| Apartment | 0.50 to 0.90 |
| Industrial | |
| Light | 0.50 to 0.80 |
| Heavy | 0.60 to 0.90 |
| Parks, cemeteries | 0.20 to 0.35 |
| Playgrounds | 0.25 to 0.40 |
| Railroad yard | 0.30 to 0.40 |
| Unimproved | 0.20 to 0.30 |

| Surface Characteristics: | Runoff Coefficient |
|---|---|
| Pavement | |
| Asphaltic and Concrete | 0.95 |
| Brick | 0.90 |
| Lattice Paver Block on Sand Base | 0.73 |
| Lattice Paver Block on Limerock Base | 0.95 |
| Roofs | 0.95 |
| Turf Slopes | |
| Flat (0 to 1%) | 0.20 |
| Gently Rolling (1 to 3%) | 0.30 |
| Hilly (3 to 10%) | 0.35 |
| Cultivated Ground | |
| Flat (0 to 1%) | 0.15 |
| Gently Rolling (1 to 3%) | 0.25 |
| Hilly (3 to 10%) | 0.30 |

## Alternate Methodologies

This section presents alternative methods for computing storm runoff in Tampa. Conventional and locally accepted methods presented herein include the rational method and the SCS method. Additionally, the USGS regression equations are discussed.

### Rational Method

The Rational Method is an empirical runoff formula which has gained wide acceptance because of its simple intuitive treatment of stormwater runoff. This method relates runoff to rainfall intensity, surface area, and surface characteristics. The Rational Method is based on 3 principal assumptions:

- The peak rate of runoff at any point is a direct function of the average uniform rainfall intensity during the time of concentration to that point.
- The frequency of the peak discharge is the same as the frequency of the average rainfall intensity.
- The time of concentration is the time required for the runoff to become established and flow from the most hydraulically remote part of the drainage area to the point under design (this assumption applies to the most remote in terms of time, not necessarily in terms of distance).

Although the fundamental principles of the Rational Method apply to drainage areas greater than 200 acres in size, practice generally limits its use to some maximum area. For the larger areas, storage and subsurface drainage flows cause an attenuation of the runoff hydrographs so that the rates of flow tend to be overestimated by this method. In addition, the assumptions for uniform rainfall distribution and intensity become less appropriate as the drainage area increases. This last consideration is particularly true in Tampa during the summer wet season when the rainfall is principally in the form of intense, highly localized convective thunderstorms. Due to the trend for overestimating flows by the Rational Method and the additional cost in drainage facilities associated with this overestimation, the application of a more sophisticated runoff computation technique is usually warranted for larger drainage areas.

The formula utilized in the Rational Method is expressed by the equation:

Rainfall intensity, I, is the average rate of rainfall in inches per hour. Intensity is selected on the basis of recurrence intervals (frequency of occurrence), a statistical parameter established by design criteria and rainfall duration. For the Rational Method, the critical rainfall intensity is the rainfall having a duration equal to the time of concentration for the drainage basin under study. Rainfall intensity can be determined for various return periods and durations from Figure 5, the FDOT rainfall intensity-duration curves for Zone 6. These curves are applicable for recurrence intervals up to the 100-year storm and for durations from 8 minutes to 24 hours.

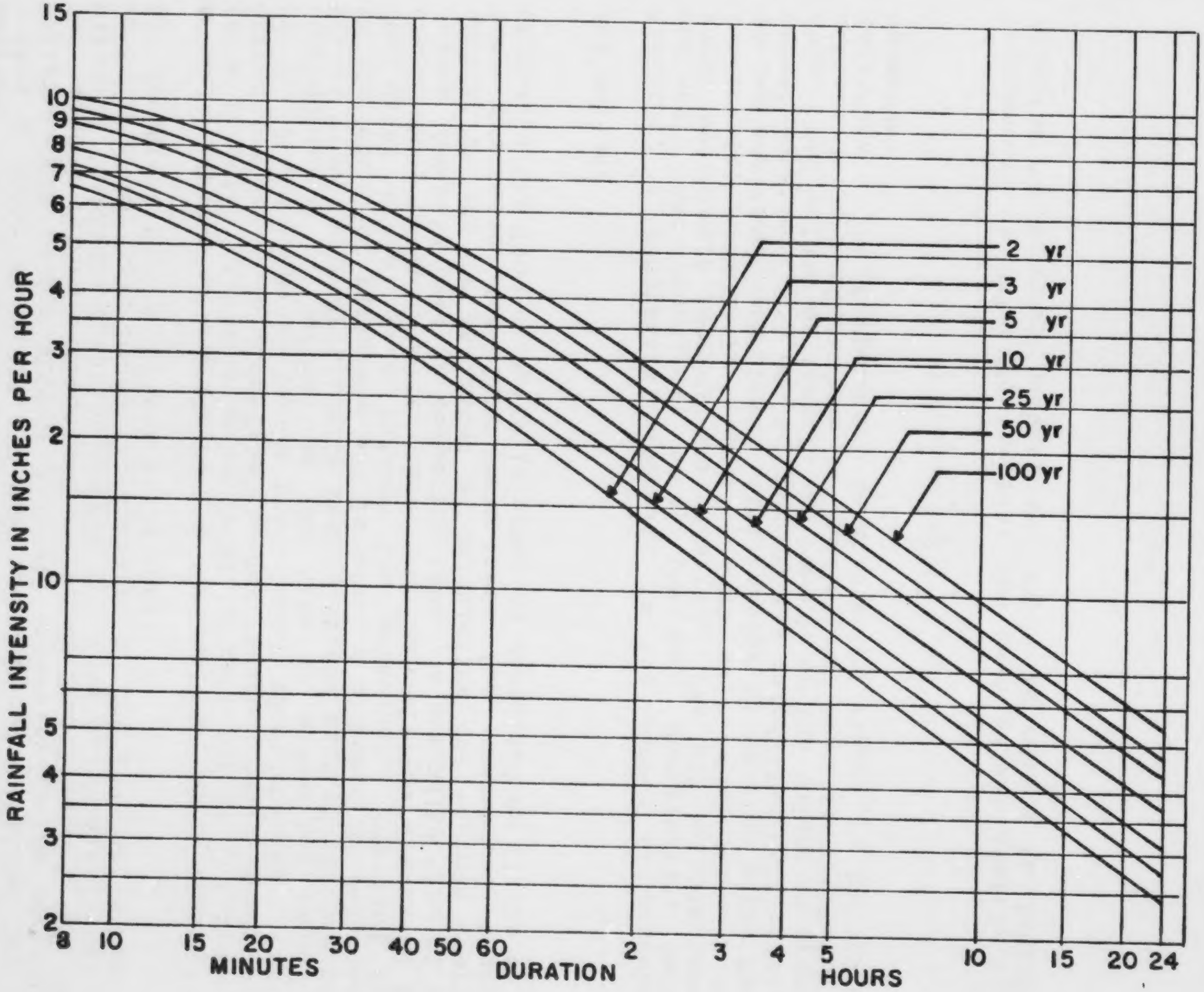
A basic assumption underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most hydraulically remote point of the drainage basin to the point under consideration. Time of concentration is defined as the time it takes for runoff to travel from the hydraulically most distance part of the watershed to the point of reference and is usually computed by determining the water travel time through the watershed. Overland flow, storm sewer or road gutter flow, and channel flow are three flow phases commonly used in computing time. A composite time of concentration can be estimated by calculating the various overland flow distances and flow velocities for individual segments utilizing the flow velocity information contained on Figure 6.

## SCS Methods

Recently, a substantial increase in the number of practicing engineers and regulators using the Soil Conservation Service (SCS) hydrologic methods has occurred. The SCS methods combine fundamental hydrologic equations with well developed and documented empirical hydrologic relationships to develop a few fundamental equations for use in solving the rainfall-runoff relationship. The volume of runoff, Q, depends on the volume of precipitation, P, and the volume of storage, S, that is available for retention. The fundamental relationships reduce to the form of equation:

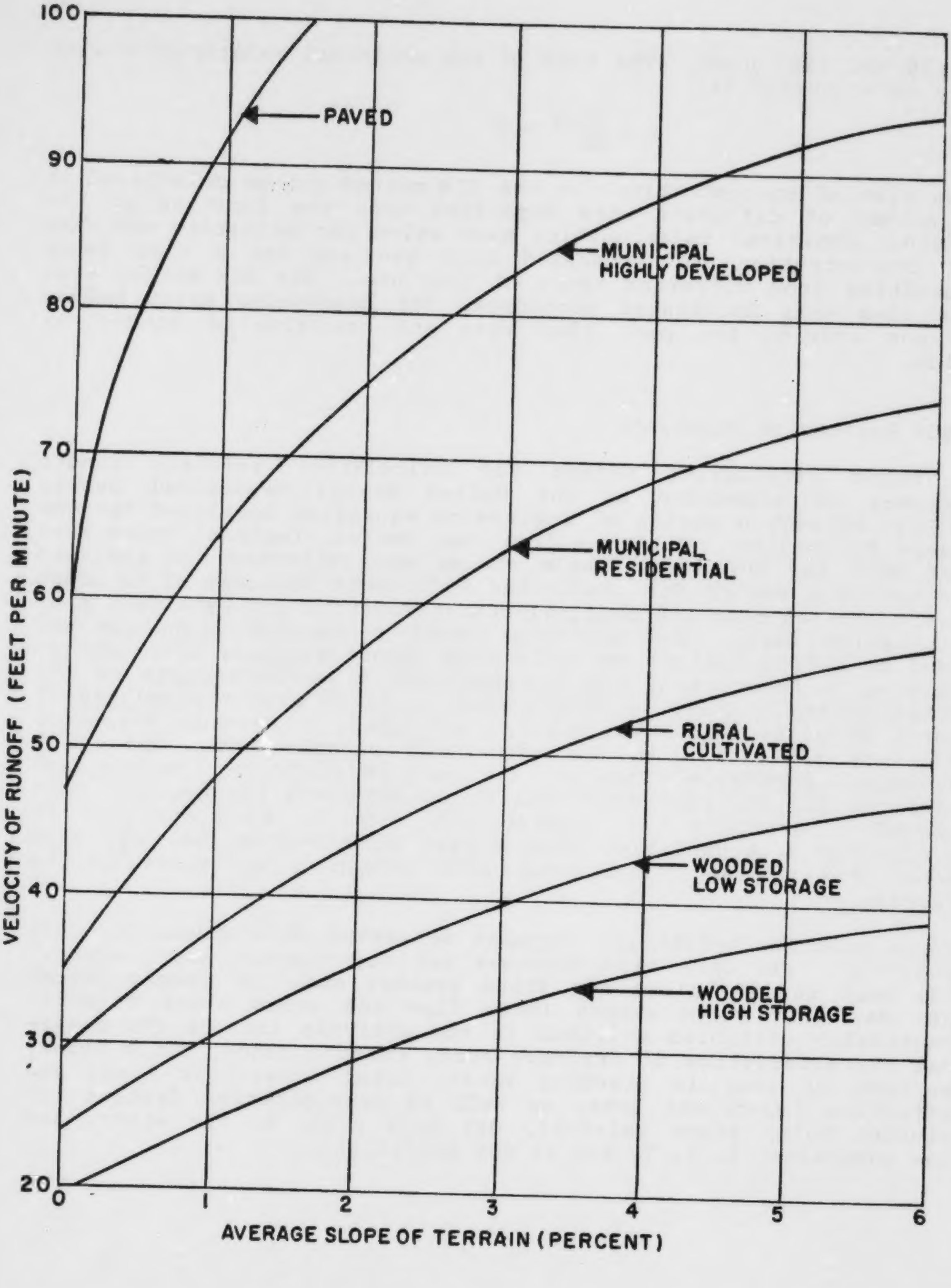
$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

Fortunately, a value for storage has been solved empirically by relating to a curve number, CN, which is unique to individual



RAINFALL INTENSITY-DURATION
ZONE 6

Figure 5



OVERLAND FLOW VELOCITY

Figure 6

soils and land uses. The form of the empirical relationship with the curve number is:

$$S = \frac{1000}{CN} - 10$$

The time of concentration for the SCS method can be calculated in a number of different ways depending upon the location of the basin. Empirical relationships also exist for adjusting the time of concentration for urbanized land use and for a time lapse resulting from different types of land use. The SCS method also includes well documented procedures for developing event hydrographs knowing the peak flow rate and the time of concentration.

## USGS Regression Equations

A third alternative method for calculating rainfall runoff volumes is presented by the United States Geological Survey (USGS) through a series of regression equations developed for the Tampa Bay Region. During a five year period, regional urban runoff data for 201 identifiable storms was collected and analyzed to derive a method for predicting hydrologic response of an urban basin knowing only the physical characteristics and pertinent precipitation data. The multiple linear regression technique was used to define spatial variations in runoff quantity characteristics as a function of the physical and climatic aspects of the urban basins. SAS76, a statistical analysis system developed at North Carolina State University, was used to develop step-wise multiple regression in the associated calculations. The SAS76 stepwise regression procedure was used in analyzing the response matrices for the nine study basins in the Tampa Bay region. This procedure examines the contribution made by each variable at every step. A variable, once a part of a regression, may exit later due to the relationship with remaining variables in the regression.

Three specific hydrologic response variables were sought for this analysis: (1) base flow response per day without storm events; (2) peak runoff values for storm events; and, (3) runoff volume per day with storm events (base flow and storm event runoff). Regression variables utilized in the analysis include the physical characteristics of drainage area, channel slope, soils index, percent of area in standing water, total impervious area, and effective impervious area, as well as precipitation factors including total storm rainfall, dry days prior to the storm, and the antecedent 1, 2, 7, and 14 day conditions.

Based on 201 storms in the nine urban basins, the following predictive models emerged from the regression analysis:

Base Flow

$$BF = 0.37\ (DA)^{1.18}\ (TRF+1)^{2.73}\ (ANT14 + 1)^{0.55}\ \text{cfs}$$

$r = 0.91$
Standard Error = ± 68%

Peak Flow Model

$$PQ = 14.45\ (DA)^{0.57}\ (EIA)\,0.61\ (TRF)^{0.75}\ (ANT2+1)^{0.20}\ \text{cfs.}$$

$r = 0.83$
Standard Error = ± 52%

Runoff Volume Model

$$RVAF = 0.36\ (DA)^{1.57} (HCIA)^{0.43} (TRF+1)^{2.24} (SHAPE)^{0.96}$$

$r = 0.97$
Standard Error = ± 27%

where:
DA = Drainage Area (sq. mi.)
TRF = Total Storm Rainfall (in.)
EIA = Effective Impervious Area (sq. mi.)
ANT2 = Antecedent 2-Day Precipitation (in.)
ANT14 = Antecedent 14-Day Precipitation (in.)
HCIA = Hydrologically Connected Impervious Area (%)
SHAPE = Basin Shape Factor

Days with less than 0.10 inch of precipitation are regarded as dry days since previous investigations have shown that 0.10 inch or more is required to cause significant runoff in urban basins.

The types of effective impervious area, the physical characteristics which cannot be directly measured from available mapping, were derived by the USGS from information on the nine urban basins. Analysis of this composite value in comparison to the total impervious area also reveals a statistical relationship with the hydraulically connected impervious area. Procedurally, for each basin,

$$COMP = 0.85\ (\%\ \text{Developed Area}) + 0.32\ (\%\ \text{Residential Area})$$

Estimate the percent hydraulically connected impervious area by

$$\mathrm{HCIA} = 1.27\,(\mathrm{COMP}) - 27.05 \qquad n = 9$$
$$r = 0.83$$

Generally speaking, use of the regression equations is more appropriate for larger drainage basins and would not be suitable for the design of small projects. A major disadvantage of this technique is that the relationship between the onset of rainfall and the time of peak is not known statistically. This shortcoming prevents preparing any meaningful hydrograph required for designing pipe controls in ponds.

Other methods can be utilized in the City and, with proper judgement, should provide suitable results. Some of these methods include unit hydrograph methods, ILLUDAS and STORM. However, recent studies which contain widely accepted algorithm coefficients that are readily defensible by the City are not in evidence. Therefore, these methods and algorithm coefficients are not discussed in this memorandum.

Based on the findings of this study, the following specific recommendations have been prepared:

- The Rational Method should be adopted as standard design and analysis method for small (less than 100 acres) studies and designs.
- More sophisticated modelling techniques should be employed in the analysis of larger, more complex studies and designs because these models provide a reasonable means of checking and revising the sizing and slopes of numerous conduits in a limited amount of time.

The selection of an appropriate digital simulation model will be predicted on the complexity of the problem, the availability of suitable data, the ultimate objective of the analysis, and the sophistication of the City's modelling staff.

# SECTION 4

# WATER QUALITY CONSIDERATIONS

Since the environmental movement focused attention on the degradation of water quality in the mid 1970's, more attention has been paid to the quality of water throughout the State by regulatory agencies. Initially, the focus was on wastewater treatment outfalls but in recent years, as non-point pollution sources have become better understood, the focus has shifted to stormwater runoff. As a result of this new awareness of the role of stormwater in water quality degradation, the impacts due to stormwater drainage must be considered in the context of the receiving water bodies.

This section summarizes the findings of the Phase II studies with regard to problem pollutants and pollutant loadings. The pollutant predictive model developed in Phase II will be described in terms of applicability and methodology along with specific design criteria. Specific load reduction goals have been developed in Task III.1 and these goals are described in this section. Finally, alternate methodologies for calculating stormwater loads are presented including the area unit load methodologies, USGS regression equations, and other widely accepted modelling techniques.

## Phase II Findings

Urban water quality runoff data collected during Phase II has been evaluated utilizing three methods: (1) single-event water quality modelling of discrete data using model SWMM; (2) statistical analysis of hydraulic and water quality composite data; and (3) comparison of Tampa stormwater data to nationwide data. Based upon these analyses, the following water quality characteristics have been determined.

- Factors which appear to impact the observed runoff quality include: dust and dirt accumulation, antecedent conditions, and rainfall intensity.
- Stormwater quality is not consistently correlated with particular storm characteristics and derived regression relationships are not statistically significant.
- Stormwater quality in Tampa is generally better than the quality documented by the nationwide NURP data set.

- The quality of rainfall in Tampa is an important source of some nutrients and metals.

## Problem Pollutants

Through analyzing water quality data collected during Phase II and during the receiving water study, a number of pollutants potentially posing problem in the receiving water were identified. Generally, the biggest problem posed by urban runoff in the transport system (from the point of generation to the receiving water) is one of too much quantity and too little capacity. Except for some eutrophic, normally wet detention/-retention ponds throughout the City and the general loss of capacity due to sedimentation, the issue of water quality is not particularly pronounced in the conveyance systems. However, as previously documented, the issue of water quality in the receiving waters and general degradation is of concern to the citizens, administrators, and regulators.

Extensive studies of the receiving waters (specifically the Lower Hillsborough River) have included long-term hydraulic and water quality monitoring at a number of points in the river, intense synoptic water quality sampling and flow monitoring, and digital simulation of the hydraulics and water quality characteristics in the Lower Hillsborough River. A very good understanding of the hydraulics and water quality mechanisms has been achieved and led to the identification of a number of problem pollutants in the receiving water. These problems include:

1. Total Suspended Solids
2. Fecal Coliform
3. Dissolved Oxygen
4. Salinity Wedge and Stratification
5. Benthic Oxygen Demand

These problems can be caused by the volume of stormwater, the quality of stormwater, or a combination of both when introduced into the receiving waters.

## Pollutant Loadings and Load Reduction Goals

Areawide loading projections developed during Phase II produced a quantification of long-term stormwater runoff flows and runoff loads for design conditions which enables an assessment of needed flooding controls and stormwater management practices based upon impacts to the receiving water. As part of this activity, the Lower Hillsborough River basin was divided into seventeen smaller catchments and hydraulic loads were estimated using the SWMM model. Knowing probable concentrations for selected water quality characteristics, the individual and aggregate pollutant loads were estimated. Utilizing these predicted flows and loads with the receiving water model and by reducing flows and loads being utilized in the receiving water model, the necessary reductions in areawide loading required to achieve desirable water quality in the Lower Hillsborough River were evaluated. These results are summarized in the outputs of Tasks II.10 and III.1.

## Tampa NURP Pollutant Load Predictive Method

There are two distinct methods for estimating storm loads originating in runoff in Tampa based on the findings of the water quality analysis: Model SWMM and the Probable Concentration Method. SWMM is a complex water quality model and is suitable for larger basins where detail is important while the Probable Concentration Method is a simpler technique suitable for either large or small basins.

### SWMM Digital Simulation Model

The water quality section of SWMM utilizes the hydraulically calibrated outflows from the transportation block and generates outflow concentrations. The water quality concentrations are based upon calibrating the model on the basis of three discrete storms at each of the five sites. Generally, SWMM provides a fairly accurate estimate of total hydraulical volume and total pollutant load. However, the prediction of "within storm" concentrations is not highly accurate. Several observations on the characteristics for the modelled basins include:

- The dust and dirt accumulation rates input to SWMM to achieve the best fit with measured data were approximately an order of magnitude less than the standard default values.

- The storm events preceeded by a long dry period obtain the best calibration by reducing the number of antecedent dry days to six. Observed BOD concentrations did not exhibit significant variation between events or even among the basins while the observed coliform concentrations were extremely variable from storm to storm and even during a single event.

- The largest peak concentrations of suspended solids and coliform were observed during storms with intense rainfall while the peak BOD concentrations did not appear to coincide with peak rainfall intensities; implying that the BOD is probably soluble and not associated with street dirt.

In lieu of design criteria for use in SWMM, Table 9 presents the water quality calibration coefficients utilized in each of the five basins as well as the default value normally utilized in the program. This table provides the basis for continuing the analysis of the existing basins and/or developing water quality models in new basins by comparing the characteristics in that basin with the characteristics of one of the five runoff characterization basins. Since water quality findings indicate that stormwater runoff in Tampa is better than in other cities surveyed, a basis for developing calibration coefficients for any new basin must be defined. Table 9 provides a localized basis for future water quality applications of the SWMM model.

For surface water quality to be simulated, additional input model data are needed for each catchment. These data are:

- Land use
- Number of catchbasins in each subcatchment
- Total length of all gutters in each subcatchment (100 of feet)
- Street cleaning frequency (days)
- Number of street sweeper passes
- Catchbasin storage volume (cubic feet)
- BOD concentration in the catchbasin water (milligrams per liter)
- Number of dry days

## Probable Concentration Method

The second method utilized to predict stormwater loads is the Probable Concentration Method. The analysis of water quality data collected during Phase II indicated that the variation in pollutant loads was more attributable to the variation in runoff volume than concentration variation. Statistical analysis of the composite data for each pollutant was conducted in order to calcu-

## TABLE 9

## INPUT PARAMETERS MATRIX FOR

## TAMPA BASINS FOR SWMM WATER QUALITY MODEL

| | SWMM Default | J.L. Young Apartments | Wilder Ditch | North Jesuit | Charter & Harding | Norma Park |
|---|---|---|---|---|---|---|
| 1. Dust and Dirt (lbs/100 LF): | | | | | | |
| - Single - Family Residential | 0.07 | -- | 0.04 | 0.50 | 0.04 | 0.01 |
| - Multi - Family Residential | 2.30 | 0.05 | 0.18 | -- | -- | -- |
| - Commercial/Institutional | 3.30 | -- | 0.26 | -- | -- | 0.02 |
| - Open Space | 1.50 | -- | 0.08 | 2.20 | 0.08 | -- |
| 2. Soluble BOD per Pound of Dust and Dirt (mg/kg): | | | | | | |
| - Single - Family Residential | 5.0 | -- | 50 | 25 | 10 | 5.0 |
| - Multi - Family Residential | 3.6 | 20 | 77 | -- | -- | -- |
| - Commercial/Institutional | 7.7 | -- | 30 | -- | -- | 7.7 |
| - Open Space | 5.0 | -- | 50 | 38 | 10 | -- |
| 3. Non-Soluble BOD Fraction | 0.05 | 0.20 | 0.60 | 0.25 | 0.10 | 0.05 |
| 4. Coliform Multiplier | 1.0 | 5.0 | 1.0 | 1.0 | 5.0 | 5.0 |
| 5. Street Cleaning Frequency (days) | 0.0 | 185 | 185 | 185 | 185 | 185 |
| 6. Number of Sweeper Passes | 0.0 | 1 | 1 | 1 | 1 | 1 |
| 7. Catchbasin Storage Volume (cu.ft.) | 0.0 | 0 | 301,500 | 0 | 0 | 0 |
| 8. Drydays | 0.0 | (Storm Dependent but never greater than 6.0) | | | | |

---

Note: -- indicates that the land use was not present in the basin.

late representative values of stormwater concentrations and the expected variation about the representative values. For selected parameters, the probability of distribution was determined and the mean and standard deviation for these distributions was calculated and is presented in the following table:

| | Minus One Standard Deviation | Mean Concentration Value | Plus One Standard Deviation |
|---|---|---|---|
| Total Suspended Solids (mg/l) | 7.9 | 22.2 | 62.4 |
| Biochemical Oxygen Demand (mg/l) | 3.8 | 14.1 | 24.4 |
| Fecal Coliforms (MPN/100 ml) | 9,030 | 25,400 | 41,800 |

The procedure for calculating pollutant loads is straight forward when using probable concentration values. Only the volume of runoff needs to be estimated and the probable concentration known in order to calculate the probable load attributable to stormwater. Normally both the range of loadings (loads associated with the plus one and minus one standard deviation concentration) and the mean probable load should be stated. The equation for calculating any load is:

$$m = 8.34\ C\ V$$

where:

m = the mass load (pounds)

c = pollutant concentration (milligrams/liter)

v = volume (million gallons)

## Alternate Methodologies

A number of alternate methodologies were reviewed to determine suitability for predicting water quality loads in Tampa. Methods reviewed included: the areal unit load method, the areal constant concentration method, USGS regression equations, and alternative modelling techniques. The criterion for evaluating these alternate methodologies was suitability for application in the Tampa Bay area based on available local data. Only the USGS regression equations are discussed in this memorandum since these are the only methods suitable for consideration.

The U.S. Geological Survey has been studying urban runoff for a number of years in Florida. Studies in both the Tampa Bay area and Broward County have utilized the multiple-regression approach to provide a means for estimating water quality characteristics for ungaged basins and for estimating the general effects of natural and cultural aspects of the drainage basins on resultant water quality. The principal advantage of this approach is that a multiple-regression model can be developed from available data and can be applied to ungaged basins for which certain physical, cultural, and environmental factors are known.

While Metcalf & Eddy, Inc. were unsuccessful in the limited multiple-regression analysis of the data collected in Phase II of the Tampa NURP Study, the USGS developed load equations for the Tampa Bay area based on data collected over a five year period in nine different basins. The six specific pollutant models were: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), total organic nitrogen (TON), total phosphorus (TP), and, total lead (TPb). Based on the selected pollutant load data collected by the USGS, the following predictive models emerged from the regression analysis:

Biochemical Oxygen Demand Model

$BOD = (-65.9) - (1.92\ PQ) + (15.3\ DRY) + (287.9\ ANT2)$ lbs.

$r = 0.92$

Standard Error = ± 44%

Chemical Oxygen Demand Model

$COD = (-1130) + (17.7\ PQ) + (96.3\ DRY) + (4705\ LUDT)$ lbs.

$r = 0.96$

Standard Error = ± 32%

Total Nitrogen Model

$TN = (-26.6) + (0.50\ PQ) + (5.1\ DRY) + (38.6\ TIA)$ lbs.

$r = 0.96$

Standard Error = ± 65%

### Total Organic Nitrogen Model

TON = (-22.64) + (0.60 PQ) + (3.8 DRY) lbs.

r = 0.88

Standard Error = ± 35%

### Total Phosphorus Model

TP = (-6.49) + (0.16 PQ) + (39.9 LUNT) lbs.

r = 0.92

Standard Error = ± 65%

### Total Lead Model

TPb = (-0.81) + (0.5 PQ) + (10.6 LUDT) lbs.

r = 0.93

Standard Error = 53%

where:

PQ = Peak Storm Flow (cfs)
DRY = Dry Days prior to Storm (days)
ANT2 = Two-Day Antecedent Precipitation (inches)
TIA = Total Impervious Area (sq. mi.)
LUDT = Land Use - Total Developed (sq. mi.)
LUNT = Land Use - Total Natural (sq. mi.)

The following recommendations have been prepared for water quality prediction based on the City's characteristics and the methods discussed:

- The probable concentration method should be utilized in general estimates of pollutant concentrations and loads for single event and/or annual estimates. This method is easily used and understood and does not require extensive, expensive analysis.
- The SWMM model should be utilized in basin planning studies for water quality estimates (particularly if it is used in hydraulic analysis) as it calculates a

reasonable storm load estimate and local algorithm coefficients are now available and the City has a version of the model up and running on its in-house computer.

## SECTION 5

## CONTROL MEASURES

During the Phase II field efforts, a number of stormwater control measures were evaluated to determine applicability in Tampa. This chapter summarizes the testing results for each of the individual devices and sets forth design criteria for future applications.

### Phase II Findings

Various stormwater controls currently used in Tampa were tested during Phase II and the results were evaluated to determine long-term abilities to attenuate and/or reduce hydraulic loads and to remove pollutants. This analysis indicated that the tested controls have a wide range of flow and pollutant removal capacities which should be considered in the design process.

Two detention/retention ponds were evaluated to determine their abilities to attenuate and/or reduce hydraulic loads as well as remove pollutants from stormwater. Unfortunately, due to budget restrictions, testing and analysis were limited to hydraulic extraction capacities for draintrench systems, open bottom inlets, and undercut ditches and swales.

### Detention/Retention Ponds

Based upon analyzing data from the field measurement program, the detention/retention ponds (which acted principally as detention ponds) are capable of reducing the peak runoff volume from stormwater, particularly if retention volume is available. Unfortunately, such retention volume is not frequently available. Retention volume, storm intensity, and duration affect the pollutant removal capability of the detention ponds. The best pollutant removals occurred during high-intensity, short-duration storms for which some retention volume was available in the ponds.

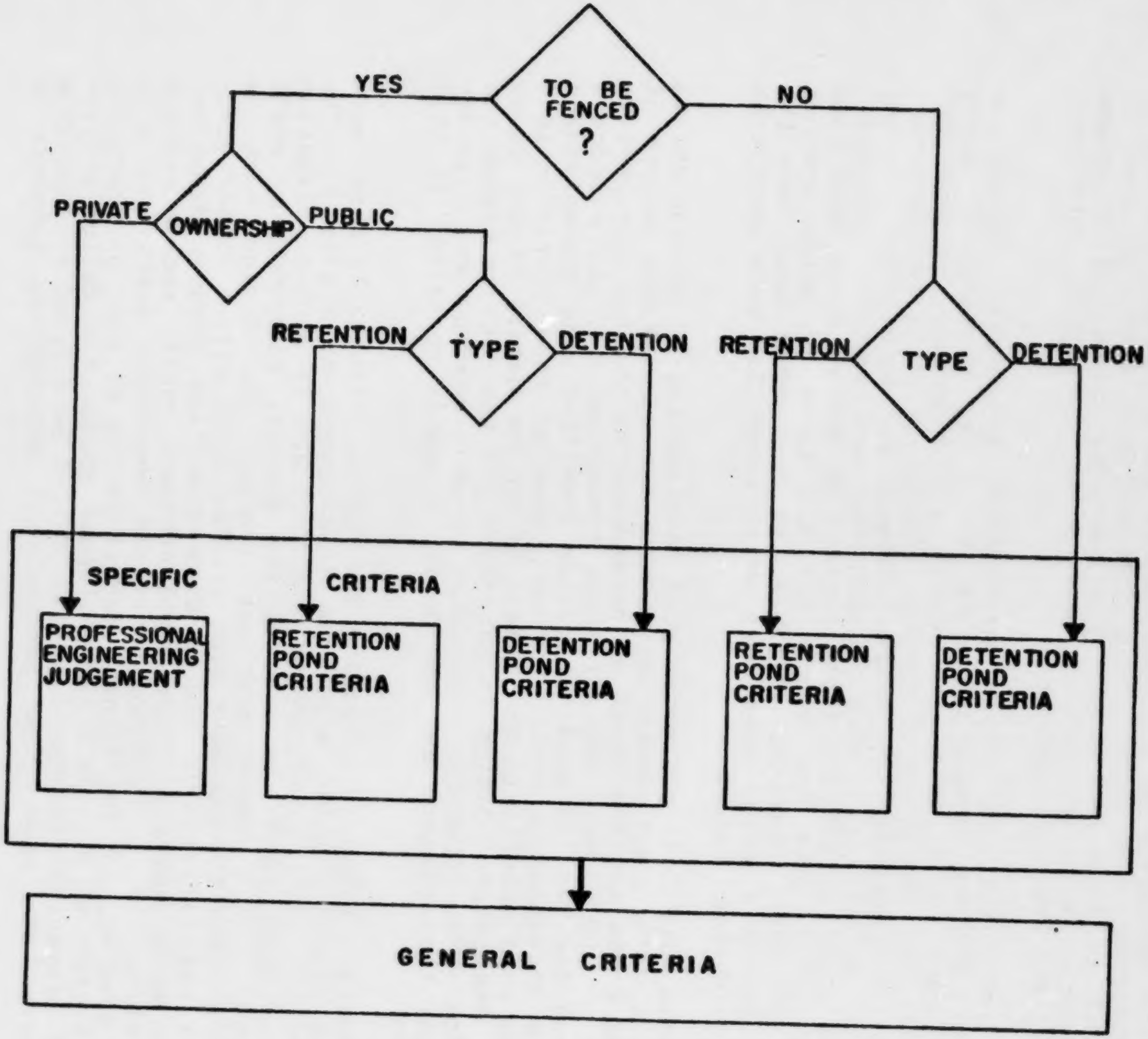
Pollutant removal was highest for pollutants associated with particulate matter and lowest for pollutants present in soluble form. Lead was removed effectively during the storm events. The treatability test results verified that lead from storm runoff settles, usually within 1 to 2 days. BOD was exerted in the tests, although most BOD contained in the runoff would be expected to escape. Other parameters did not show clear patterns of settling. In-pond water samples usually reflected a "steady-state" concentration for most pollutant parameters over a 6-day sampling period.

Retention/detention pond costs vary more than other stormwater controls due to size, cost, and the range of auxillary structures necessary for properly utilizing the site. An area/cost relationship cannot be developed due to the variability in pond designs which are dependent on the groundwater table, shape, and available storage. The annual cost for mowing a detention pond is estimated at $136 per acre. The cost for fence and structure maintenance, washout repairs and other operations are very specific and were not estimated.

Design criteria for this particular stormwater management practice becomes complicated due to: two classes of ponds (fenced and unfenced); two types of ownership (public and private); and two types of devices (detention ponds and retention ponds). Fortunately, the design criteria can be divided into two distinct categories: general criteria and specific criteria. General criteria address those aspects of design which have been set by policy and are common for all types of ponds whether fenced or not. Specific criteria, on the other hand, are the design criteria which have been established for each pond type based on whether fenced or not.

The Tampa City Code addresses pond construction in Section 45-396 and goes into great detail concerning the appropriate method of grading ponds and the depth as determined by whether the pond is fenced or not. Many jurisdictions throughout the state address the need for fencing ponds at either specified side slopes and/or certain threshold depths. However, none of these jurisdictions address pond grading to the extent or in the detail of the Tampa Code. The recommendation is put forth for the City to review the need for such excessive regulation of pond grading and consider adopting the approach and the design criteria contained in this section.

The approach taken in preparing the design criteria is based upon a pond classification algorithm illustrated on Figure 7. The fundamental concept underlying this approach is public obligation with unfenced ponds to protect the public, particularly small children. When ponds are not fenced, the design must be relatively shallow and have side grading which allows an individual who has fallen into the pond to crawl out without drowning. On the other hand, a fenced pond prevents public access and can be designed to a different standard regarding depth and side slope grading. A fundamental consideration of this approach is, in the case of privately owned fenced ponds, the design professional preparing the drainage plan should be allowed the latitude to design the pond using professional engineering judgment in


TO BE FENCED ?
YES
NO
OWNERSHIP
PRIVATE
PUBLIC
TYPE
RETENTION
DETENTION
TYPE
RETENTION
DETENTION
SPECIFIC CRITERIA
PROFESSIONAL ENGINEERING JUDGEMENT
RETENTION POND CRITERIA
DETENTION POND CRITERIA
RETENTION POND CRITERIA
DETENTION POND CRITERIA
GENERAL CRITERIA

POND DESIGN FLOW CHART

Figure 7

such a fashion that the pond can meet the hydraulic objectives without undue concern for the grading plan. In the case of a fenced public pond, specific design criteria should be established for allowing deeper ponds and steeper side slope grading than the design criteria for unfenced ponds.

Figure 7 indicates that all ponds must be designed on the basis of general criteria and specific criteria are only applicable to that particular class of ponds. The recommended general criteria include:

- o Setback from the property line and/or right-of-way lines of 5 feet (minimum).
- o Landscape berm at a minimum of one foot above existing grade in the 5 foot setback from property and lot lines.
- o Bank stabilization, dependent on side slope, as follows:

| Method of Protection | Acceptable Ranges | | |
|---|---|---|---|
| | % Grade | Rise:Run | Angle |
| Hydro-Mulching & Seeding | 0-25 | Flat-1:4 | 0°00' -14°02' |
| Sodding | 26-75 | 1:4 -3:4 | 14°03'-36°52' |
| Staked Sodding | 76-100 | 3:4 -1:1 | 36°52'-45°00' |
| Lattice Block | 101-150 | 1:1 -3:2 | 45°01'-56°18' |
| Rip-Rap | 151-250 | 3:2 -5:2 | 56°19'-68°12' |
| Retaining Wall | 251-Vertical | 5:2 -Vertical | 68°13'-90°00' |

Percolation rates for ponds will be determined in the following fashion dependent upon project or site drainage size:

Small Projects

Definition - Composite impervious area less than 10,000 square feet.

Large Projects with Single Percolating Ponds

Definition - Composite impervious area equal to or greater than 10,000 square feet.

## Large Projects with Multiple Percolating Ponds

Definition - Composite impervious area equal to or greater than 10,000 square feet.

Case I:

Requirement - Contributing impervious area less than 10,000 square feet for the pond in question.

Test - Standard Septic Tank Test (10D-6) after site saturation for 3.0 hours.

Adjustment - Field percolation rate expressed in feet/hour adjusted by a 4.0 safety factor per current City policy.

Limitation - No adjusted rates in excess of 1.5 feet/hour will be accepted without verification by double ring infiltrometer test results.

Case II:

Requirement - Contributing impervious area equal to or greater than 10,000 square feet for the pond in question.

Test - Modified (36" outer ring) double-ring infiltrometer test(s) (as used by Hillsborough County) with the number of individual test sites determined on the basis of project size as follows: one site (agreed upon by the City and Engineer) per 0.5 acres of pond bottom with a minimum of one test per pond.

Adjustment - Field percolation rate expressed in feet/hour adjusted by a 1.25 safety factor.

Limitation - No adjusted percolation rates in excess of 2.5 feet/hour will be accepted.

- Borings will be required for all ponds to document subsurface conditions below proposed ponds and are to meet the following requirements:

    Depth - to a depth of ten (10) feet below the proposed pond bottom.

    Report - standard boring report which documents subsurface strata, depth to water table after 24 hours, and estimated depth to seasonal high water table.

Numbers - the number of borings will be determined on the basis of 1 boring per 0.33 acre of pond bottom with a minimum of two (2) borings per pond.

Location - the location of the borings will be agreed upon by the City and the Engineer of Record and located in a manner to provide the maximum appropriate information.

- Freeboard requirements are a minimum of one (1.0) foot and is defined as the minimum elevation difference between the Design High Water (DHW) and the lowest point in the landscaped berm which surrounds the pond or the gutter adjacent to the pond, whichever is lower.
- Fenced Ponds must provide an access barrier to protect the public which is continuous and meets the following criteria:

Fence Height - Six (6) feet minimum.

Access Control - A locked gate of the same height as the fence and must be provided which has a suitable width for the maintenance of the pond by appropriate measures. A suitable access easement between the fence and the edge of the pond must be provided to facilitate maintenance.

| MINIMUM CRITERIA | Gate Width (ft.) | Maintenance Easement (ft.) |
|---|---|---|
| **Municipal Ponds:** | | |
| Manually Cleaned | 4.0 | 5.0 |
| Mechanically Cleaned | 16.0 | 20.0 |
| **Private Ponds:** | | |
| Manually Cleaned | 4.0 | 5.0 |
| Mechanically Cleaned | 10.0 | 15.0 |

**Materials** - The standard fencing material is commercial gauge, galvanized posts and chain-link fabric with the following standard dimensions:

| | |
|---|---|
| Fabric | 2 inch diamond, 11 gauge |
| Terminal Post | 2.375" O.D. x 0.130" T. |
| Line Post | 1.900" O.D. x 0.120" T. |
| Line Posting Spacing | 10.0 ft. (maximum) |
| Gate Post | 4.000" O.D. x 0.160" T. |
| Top Rail | 1.375" O.D. x 0.095" T. |
| Tension Bar | 1/4" x 3/4" x 70" |
| Tension Wire | 0.192" O.D. attached at 15" O.C. |

Alternative materials may be approved for use for aesthetic purposes provided that they are to be well maintained and provide the same degree of access control.

Specific pond design criteria as specified for: (1) fenced ponds of private ownership, (2) fenced ponds of public ownership, and, (3) unfenced ponds of either public or private ownership. Specific criteria for these individual conditions are as follows:

Private Fenced Ponds:

- Suitable side slopes to be determined on the basis of soils stability characteristics and/or stabilization methods to be employed based upon volumetric and economic considerations.
- Suitable depth of pond to be determined on the basis of necessary volumetric storage requirements and depth to the seasonal high water table elevation.
- Distance between the seasonal high groundwater table and the bottom of the pond shall be unrestricted for retention ponds and shall be a minimum of 1.0 feet for detention ponds.
- Detention ponds shall be sized on the basis of the 25-year/24 hour design storm for Zone I (low-intensity) and 50-year/24-hour design storm for Zone II (high-intensity) land uses with adjusted, field documented percolation rates accounting for losses after 15 minutes.

Publicly Owned Fenced Retention Ponds:

- Side slopes are governed by the normal depth of water in the ponds -

Shallow ponds - these ponds have less than six foot depths during the majority of the year and do not (normally) function as healthy lakes but tend to be eutrophic and overgrown with weeds.

- o Side slopes will be limited to 1V:3H (maximum) for ponds which do not provide an adequate maintenance easement but shall not exceed 2:1 for ponds with adequate maintenance easements.

Deep ponds - these ponds have more than six foot depth throughout the year and, when properly operated and maintained, tend to be healthy and maintain suitable water quality. Ideally, deep ponds for major facilities should include a litoral shelf at the perifery of the lake graded at 1:6-1:10 and located between the seasonal high and low water tables. Side slopes approaching the litoral shelf from the top of the landscaped berm should not exceed 1:3 (maximum) for ponds which do not provide an adequate maintenance easement and 2:1 (maximum) for those ponds which do provide an adequate easement. Slopes below the litoral shelf should be limited to the range of 1:1 to 2:1 dependent upon soil characteristics.

- o Retention volume shall be calculated as the storage volume available between the design high water (DHW) level and an elevation equal to the seasonal high water table (SHWT) plus 0.50 feet.

- o Retention ponds shall be sized on the basis of the 50-year/24-hour design storm for Zone I (low-intensity) and the 100-year/24-hour design storm for Zone II land uses with no losses attributable to percolation for the first hour. Retention Ponds will not be built on clay soils.

Unfenced Detention Ponds:

- o Side slopes will be limited to a maximum of 1:3 from the top of the landscaped berm to a point four (4) feet below the SHWT and beyond this point the side slopes

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will be limited to 2:1 (maximum) to the bottom of the pond.

- Depth is unrestricted except in respect to the seasonal high water table (SHWT).
- Distance between seasonal high table and bottom of pond shall be a minimum of 1.0 feet for ponds that normally drain dry and the Design Low Water (DLW) elevation for normally wet ponds shall be established as the SHWT elevation + 0.25 feet.
- Detention ponds shall be sized on the basis of the 25-year/24-hour design storm for Zone I (low-intensity) and 50-year/24-hour design storm for Zone II (high-intensity) land uses with adjusted, field documented percolation rates accounting for losses after 15 minutes.

Unfenced Retention Ponds:

- Side slopes are governed by the normal depth of water in the ponds -

Shallow Ponds - these ponds have less than six foot depths during the majority of the year and do not (normally) function as healthy lakes but tend to be eutrophic and overgrown with weeds. Side slopes shall be limited to 1:3 (maximum) from the top of the landscaped berm to the bottom of the pond.

Deep Ponds - these ponds have more than three foot depth throughout the year and, when properly operated and maintained, tend to be healthy and maintain suitable water quality. Ideally, deep ponds for major facilities should include a litoral shelf graded at 1:6-1:10 and located between the seasonal high- and low water tables. Slopes from the top of the landscaped berm to the litoral will be limited to 1:3 (maximum) and slopes from the litoral shelf to pond bottom should be in the range of 1:1 (minimum) to 2:1 (maximum).

- Retention ponds with a litoral shelf should limit the design retention depth to 2.0-2.5 feet with a maximum depth (in excess of 24 hours) of 3.0 feet.

- Retention volume shall be calculated as the storage volume available between the design high water (DHW) level and an elevation equal to the seasonal high water table (SHWT) plus 0.50 feet.

- Retention ponds shall be sized on the basis of the 50-year/24-hour design storm for Zone I (low-intensity) and the 100-year/24-hour design storm for Zone II land uses with no losses attributable to percolation for the first hour.

- Distance between seasonal high groundwater table and bottom of pond is unrestricted.

These general and specific design criteria should provide the guidance necessary to design functional ponds. The following recommendations are based on local experiences and recent proposed changes in FDER's Stormwater Rule.

- Wherever possible, ponds should be designed to drain dry, either through bleed-down or percolation, after the design event in a reasonable amount of time (24-72 hours). This will prevent the occurrence of on-going problems associated with small shallow ponds: complaints originating from odors, weeds, snakes, rats, insects (particularly mosquitos), and green "slime".

- Underdrains which allow ponds to dry out must be carefully designed in order to properly function for a reasonable design life while providing limited water quality benefits and while shaving peak flow rates. An 8" PVC perforated lateral pipe is recommended as a minimum standard and the proposed new FDER standards for granular filter material (17-25.02(4), proposed revisions of June 30, 1983) will require analysis of locally available sands to determine suitability for use in underdrain designs.

- When designing major ponds with a litoral shelf, existing plantings from City ponds could be used as planting stock, bunches rather than individual plants be used in vegetating the shelf, and the bunches be planted on 3-foot centers. Cattails (Typha species) are excellent shore stabilizers and should be planted shoreward in conjunction with such species of emergent vegetation as sweet flat (Acous calamus), arrowheads (Sagittaria), or pickerelweed (Pontederia cordata). Reedcane (Phragmites) or panicgrass (Panicum) can also be planted on the shallower parts

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of the shelf. Submerged species of macrophytes including eelgrass (Vallisneria) or widgeon (Ruppia) should be planted on the deeper portions of the shelf. Species that form large, floating mats such as hydrilla (Hydrilla verticillata) are to be avoided, although Hydrilla and water hyacinths (Eichornia crassipes) frequently appear in lakes without having been planted.

## Drain Trench Systems

Drain trench testing indicated that the hydraulic and pollutant removal rate generally ranges between 30 and 35 percent of the inflow rates for dry and wet weather conditions. Drain trenches are more costly to construct and maintain but the underground location in the right-of-way is a desirable feature.

The outflows observed for drain trenches indicate that a long-term hydraulic removal rate of 30 to 35 percent is attained. Given the test time lengths, the results imply that drain trenches can continue to achieve this removal rate during most rainfall events. The dry or wet weather removal capacity of drain trenches is dependent on storm characteristics. A drain trench may perform better during a low-intensity storm in wet weather than a high-intensity storm in dry weather. However, tests also indicate that drain trenches can not always be relied upon for large volumetric removals due to obstruction of the inlet pipe, hydraulic over-loading from intense rainfall events, and saturated soil conditions.

A uniform trench cross-section 3.0 ft. wide, 2.0 ft. deep with an 8-inch diameter perforated pipe is used by the City to simplify the design and construction process. The initial selection was based on an extensive unit cost ($/cu.ft. removed/event) optimization study which analyzed the numerous combinations of widths (2'-4'), depths (2'-4'), and pipe diameters (8", 12", 18" and 24"). A 1982 unit cost of $21.13/lin. ft. has been provided for this type of control. Drain trenches maintenance includes cleaning the culvert by jet and vacuuming the inlet about twice a year. For a 75 foot trench extending from an inlet, the annual maintenance cost would be $26.70. A maximum usage of two 75 foot trenches extending from one inlet would cost $42.40 to maintain.

Based upon this analysis, the following design criteria are recommended:

- Uniform cross-section of 3.0 feet wide by 2.0 feet deep with an 8-inch diameter perforated PVC lateral pipe.

- The lateral pipe should be located in the center of the width of the gravel bed and the crown of the pipe should be six inches below the top of the gravel trench.

- A minimum of ten inches should separate the invert elevations of the drain trench lateral pipe and the overflow pipe to the storm sewer pipe having the higher elevation.

- The lateral pipe to the drain trench should be a minimum of one foot above the bottom of the catchbasin.

- The catchbasin should be set on a twelve inch gravel bed and should extend beyond the outside surfaces of the catchbasin by a minimum of six inches. The bottom of the catchbasin should be perforated with an 8-inch diameter opening in the bottom of the slab to allow surplus water to enter the gravel pack.

- The gravel utilized in the trench should be clean, washed material which will not pass a 3/4-inch screen but readily passes a 1 1/2-inch screen with fairly uniform gradation between those two sizes.

- The gravel bed should be wrapped with a filter fabric (Mirafi #140 is presently being used) across the top of the gravel and half way down each side to prevent the migration of fines from the backfill material into the gravel bed and decreasing capacity.

- The cleanout presently included as a part of the standard City design may not be necessary as the City's jet-vactor can clean the lateral pipes from the catchbasin without the need for the cleanout fittings.

- Maximum standard trench run not to exceed 100 feet.

- Soil borings should be required for each trench run.

- Parallel trench runs should be served by separate lateral pipes (to the inlet) to facilitate cleaning.

- Parallel trench runs should be separated by 3.0 feet (minimum) to facilitate percolation.

## Open Bottom Inlets

Control tests performed on open bottom inlets indicated that, in general, the available void spaces in the gravel pack on the outside of the catchbasin had not been utilized for disposal of runoff extracted from the catchbasin. The present design standard for open bottom inlets (specifically, the Mirafi filter fabric lining the inside of the catchbasin) appears unfavorable for significant runoff removal because the design tends to limit the storage to the interior gravel pack. Although open bottom inlets are inexpensive and easy to construct and maintain, the value is limited due to ineffectiveness under existing design and maintenance practices. Additionally, groundwater saturation of the gravel pack on the outside of the catchbasin may cause reduced capacities during period of high groundwater level. Generally, the pollutant removal is limited to the amount of volume removed.

Given the problems with the current design, open bottom inlets should be constructed with a modified design and these inlets tested to determine whether performance is improved over the current design in terms of volumetric removal characteristics. Specific modifications would involve either removing the filter fabric from the interior gravel pack totally, thus allowing fines to enter the gravel pack outside the catchbasin, or constructing the open bottom inlet in a fashion similar to current practice except when installing the interior gravel pack place the majority of the gravel first, then filter fabric, and then a 6" gravel cover to keep the fabric in place. This would facilitate easy removal of the fabric on a periodic basis while still protecting the overall gravel pack from silt and fines.

Design criteria recommendations for open bottom inlets based on field testing and analysis of current design include the following:

- Modify the gravel pack material specification to well washed, clean gravel which does not pass the 3/4-inch screen, passing the 1 1/2-inch screen, and with fairly uniform gradation.
- Delete the top 1.0 feet of gravel in the external gravel pack (above the overflow line to the sewers) the head of the water in the catchbasin is unlikely to exceed the capacity of this pipe and drive the static water levels in the gravel pack above the crown of the discharge pipe.
- Modify the interior gravel pack construction as previously described to prevent fines from clogging and limiting the extraction volume to the void space in the interior gravel pack.

- Attempt to prevent construction of gravel pack below the seasonal high groundwater elevation.

- Maintain a one-foot gravel jacket around the exterior of the catchbasin since anything larger becomes difficult to construct due to lateral restrictions in most right-of-ways. Wrap the external gravel pack from the bottom of the gravel bed to the top and for one foot above the shoulder of the gravel jacket with a geotextile filter fabric (Mirafi-140 is presently used) to prevent the migration of fines from the backfill material.

## Swales and Minor Ditches

Based on a ditch system and swale test results, the system appears to have a wet and dry weather removal capacity equal to or superior to drain trenches. The long-term removal rate for swales ranges from 27 to 69 percent of the inflow with an average value of 43 percent. For undercut ditches, the removal capacity is between 47 percent and 69 percent of the inflow with an average value of 56 percent, approximately 30 percent higher than swales. Duration testing indicates that swales and ditch systems appear to be capable of sustaining these removal rates through most storm events.

Based upon reviewing yearly ditch maintenance costs, surveying, sodding, and excavation costs total approximately $5.70 per foot for either a swale or an undercut ditch. Estimates for maintenance costs associated with minor ditch regrading at five years intervals are about $0.52 per foot.

Based on analyzing the typical cross-sections tested in surveying swale and ditch design, the following design criteria are proposed for minor ditches:

- Maximum bottom slope limited only by the design treatment of the ditch as follows -

  Soil-Lined Ditches will limit maximum design velocities to the following non-scour velocities:

| Soil | Maximum Velocity (fps) |
|---|---|
| Silt or fine sand | 1.50 |
| Sandy Loam | 1.75 |
| Silt Loam | 2.00 |
| Firm Loam | 2.50 |
| Stiff Clay | 3.75 |
| Hard Pans | 6.00 |

Grass-Lined Ditches will limit maximum design velocities to 5.0 feet per second but peak velocities may be restricted when vegetative linings cannot be relied upon to provide protection because design conditions do not allow for long-term health. The conditions where grass cannot be expected to remain in satisfactory shape include but are not limited to:

Where velocities in excess of 5.5 fps would occur.

Where there will be long standing or continuous flowing water.

Areas which do not receive the regular maintenance necessary to prevent domination by taller vegetation.

Areas where sod will be excessively shaded.

- A bottom width of 1.0-1.5 feet.
- Top width of 6.0-7.0 feet.
- General depth of ditch proper not to exceed 2.0 feet.
- Velocity of stormwater in the ditch section not to exceed 5.0 feet per second under design conditions.
- Headwalls required where culverts are required in ditch sections for driveways or street crossings.
- Maximum design capacity for undercut ditches of 20.0 cubic feet per second under design conditions.
- A minimum freeboard of 0.75-1.00 feet between design high water in the ditch and adjacent finished grade of properties and/or street elevations in order to prevent flooding.
- Ditches should be routinely designed to undercut the invert-to-invert grade line by 0.5-1.0 foot to retain stormwater and increase percolation provided that the undercutting does not put the ditch bottom elevation below the seasonal high water table.
- Ditches should be designed to drain and percolate to a dry condition within 12-18 hours after the storm event within a maximum time of 24 hours.

General design criteria for swales, based on literature and ordinance review are as follows:

- Side slopes limited to 1:6 (maximum) - 1:8 (minimum).
- All swales protected at time of construction on the basis of longitudinal slope as follows:

| Slope (%) | Protection |
|---|---|
| 0.1%-1.0% | seed and mulch |
| 1.0%-2.0% | sod |

- General depth of the swale proper not be exceed 2.0 feet.
- Velocity of stormwater in the ditch not to exceed 5.0 feet per second under design conditions.
- Maximum design capacity for grassed swales of 30.0 cubic feet per second under design conditions.
- A minimum freeboard of 1.0 feet between the design high water in the ditch and adjacent finished grade of properties and/or street elevations in order to prevent flooding.
- No culverts or crossings (other than clear span) permitted.

# APPENDIX D

# DRAINAGE SYSTEM DESIGN

## General

This Appendix provides input to the City's SMP on a methodology for design of major and minor drainage sytems. Existing City drainage design practices have been revised and updated to incorporate findings of the Tampa NURP study and other current design standards. A separate methodology is provided for design of major and minor systems, along with rationals for distinction beteen the two types of systems. The methodologies incorporte both stormwater quantity and quality considerations, coordinate design procedures with desired stormwater load reductions, and aim towards achieving consistency with current DER stormwater permitting regulations.

## Current City Drainage Design Practices

Existing City design practice is based upon an internal memorandum (1). The peak runoff rate for storm sewer design is calculated using the Rational method, in which:

$Q_p$ = RcIA where

$Q_p$ = peak runoff rate (cfs)

Rc = runoff coefficient

I = average rainfall intensity (inch/hr) lasting for a critical period of time, $t_c$

$t_c$ = time of concentration of the drainage area

A = drainage area size (acres)

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Rcs are as follows:

Commercial = 0.895

Industrial = 0.75

Medium Density Residential = 0.40

Low Density Residential = 0.30

Open/Natural = 0.15

Average intensity is determined using the Florida Department of Transportation (FDOT), 5 year intensity-frequency-duration (IFD) curve for Zone 6, Tampa. Time of concentration is determined from the Velocity of Runoff Chart in the FDOT Drainage Manual.

The sizes of pipes and ditches that will just flow full for $Q_p$ are determined with Manning's Formula. The values of Manning's n are as follows:

15 - 30 inch RCP, n = 0.013

36 - 48 inch RCP, n = 0.012

> 54 inch RCP, n = 0.011

Concrete Boxes, n = 0.010

Ditches, n = 0.030

Minimum and maximum velocities in pipes are 2.5 and 15.0 fps respectively.

The spacing between manholes depends on the pipe size as follows:

| Pipe diameter (inches) | Spacing between manholes (feet) |
|---|---|
| 18 | 300 |
| 24 - 36 | 400 |
| >42 | 500 |

Detention ponds are designed based on the 25 year IFD, FDOT curve for Zone 6 Tampa using a 24 hour duration unless maximum capacity requirements are obtained under less duration. Retention ponds are designed based on the 50 year IFD FDOT curve using a 24 hour duration.

## Distinction Between Major and Minor Systems

In the City of Tampa, major drainage systems refer to the major drainage subareas of a large drainage basin such as the lower Hillsborough River basin. These subareas can be several hundred acres in size, such as the Sunshine Park basin, which was used as a case study in developing the SMP. Minor drainage systems are the subsystems within a major system.

The distinction between major and minor drainage systems is not always definitive and may require evaluation of case-specific concerns by the City staff. For example, a major pipe which drains directly to the lower Hillsborough River that drains an area of less than 100 acres may be designated a major system by the City.

Existing city design practices make no official distinction between major and minor systems. The Rational method could be used for either type. However in the City's recent Master Drainage Planning efforts (of major drainage systems), the SWMM has been used as a planning and design tool. Therefore, there is some precedent for the use of different design methods for differet size basins.

Separate drainage design methodologies have been developed for both major and minor systems. The demarcation between major and minor systems is dependent upon two concerns. One is the inherent limitation in the Rational method approach. It is invalid to use this method in drainage systems greater than about 200 acres (2) because non-peak flows, for which this method does not account, become more important as basin size increases. Thus a lower bound is established for the size of a major system where more detailed analyses such as SWMM are required. For areas less than 100 acres, the Rational method is clearly valid and can be used. For areas between 100 and 200 acres, both methods can be considered. The major system analytic approach involves the SWMM, which is relatively expensive in that it requires access to a main frame computer and specialized engineering expertise. The following factors must be evaluated to determine the need for SWMM modeling:

1. The value of the system area and properties adjacent to it that may be affected by flooding in the area.
2. The agency, whether city or private, being held responsible for the design.

For low value district drainage systems of less than 200 acres, the City may deem it appropriate to use the Rational method. However, in high value districts, SWMM could be used for City designed systems. SWMM can always be used even for very small areas, and it will still provide accurate results. However, City staff designing small systems and private developers may not require this level of design detail.

Therefore, for purposes of this Appendix, major system design refers to applications which use SWMM and are often greater than 100-200 acres. Minor system design uses the Rational method, and applies mainly to areas less than 100-200 acres.

## Major System Drainage Design

The major system drainage design follows closely the preliminary planning, detailed planning and design and construction phases proposed during the Stormwater Management Plan presented in Chapters 2, 3 and 4 of Volume I of this Study. These phases are illustrated in Figure D-1. Each phase is discussed in some detail below.

Preliminary Planning Phase. The preliminary planning phase facilitates stormwater management on a large scale. During this phase, the flood prevention requirements of the major system are estimated. If the major system area corresponds to a subarea of the lower Hillsborough River basin as designated in Chapter 2 of this Study, then these requirements have already been calculated. Evaluation of such requirements allows prioritization of the major system with respect to the other major systems within the City that may require drainage system work. The following steps are involved in preliminary planning:

1. Identify flooding problems,
2. Identify quality problems,
3. Develop flooding solutions,
4. Develop quality solutions,

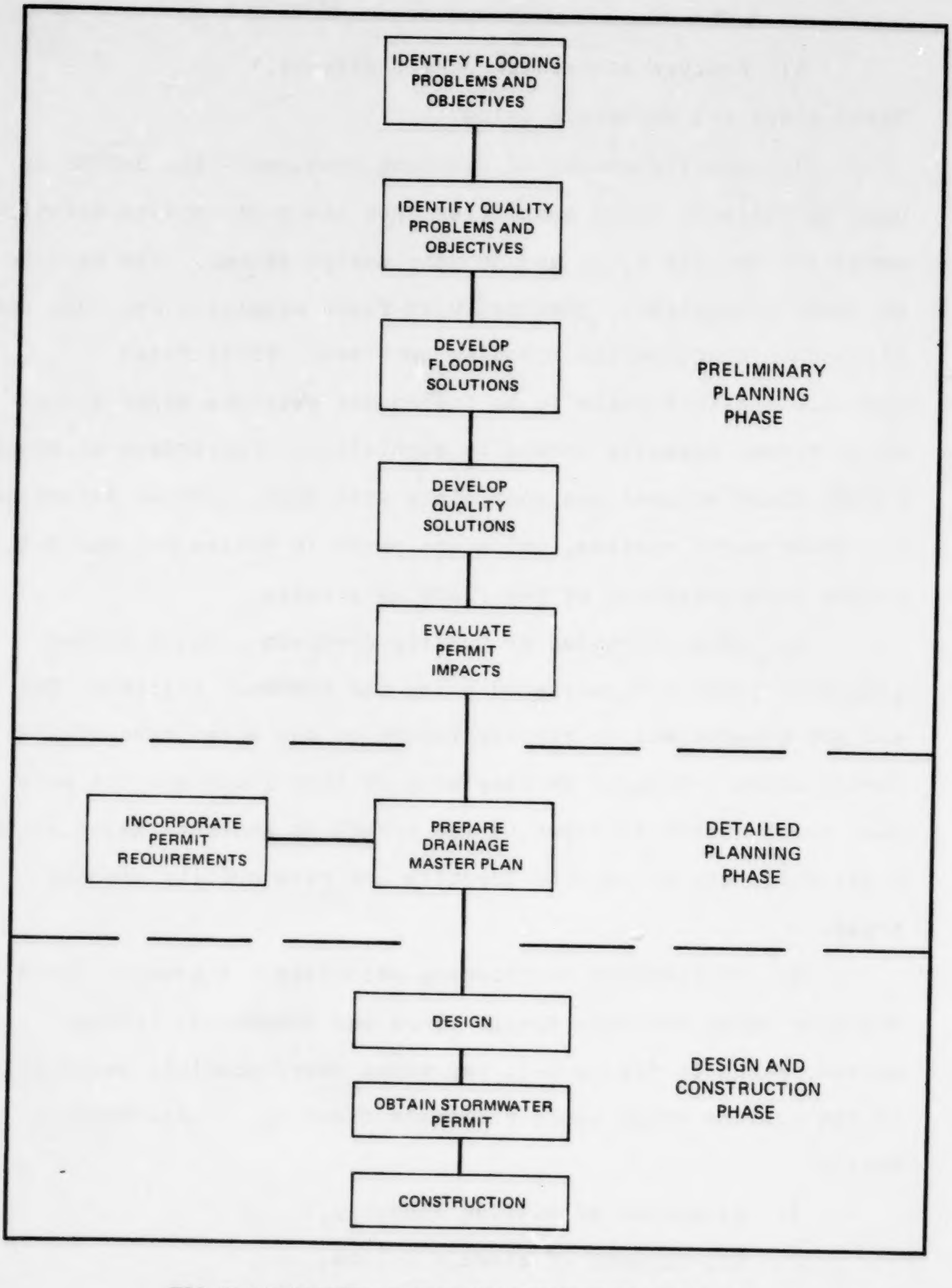
IDENTIFY FLOODING PROBLEMS AND OBJECTIVES
IDENTIFY QUALITY PROBLEMS AND OBJECTIVES
DEVELOP FLOODING SOLUTIONS
PRELIMINARY PLANNING PHASE
DEVELOP QUALITY SOLUTIONS
EVALUATE PERMIT IMPACTS
INCORPORATE PERMIT REQUIREMENTS
PREPARE DRAINAGE MASTER PLAN
DETAILED PLANNING PHASE
DESIGN
DESIGN AND CONSTRUCTION PHASE
OBTAIN STORMWATER PERMIT
CONSTRUCTION

FIG. D-1 STORMWATER MANAGEMENT PROCEDURE

5. Analyze stormwater permit effects.

These steps are described below.

1. Identification of Flooding Problems - The S/SWMM is used to estimate flood quantities from the major system existing condition for the 5, 25 and 50 year design storms. The results of these simulations, combined with flood complaint records, can be used to characterize flooding problems. Those flood complaints attributable to an inadequate existing major storm sewer system capacity should be quantified. Comparison of these S/SWMM flood volumes and complaints with those already determined for other major systems, which are shown in Tables D-1 and D-2, allows prioritization of the flooding problem.

2. Identification of Quality Problems - Major system pollutant loads are generated using the S/SWMM. Coliform, TSS and BOD concentrations representative of the worst case quality design storm developed in Chapter 3 of this Study and the worst case event should be input to the S/SWMM to generate major system loads which can be used to identify and rank quality problem areas.

3. Development of Flooding Solutions - A general flood solution curve for each design storm was developed. These curves, shown in Figure D-2, represent every possible combination of the options which would eliminate flooding. These options are:

1. Expansion of outflow capacity,
2. Enlargement of storage volume,
3. Reduction in runoff volume.

## TABLE D-1. SUMMARY OF FLOODING VOLUMES (MG) FOR DESIGN STORMS

| Major System | Abbrv. | Design Storm Frequency (years) 5 | 25 | 50 |
|---|---|---|---|---|
| Forest Hills | FH | 109 | 162 | 171 |
| Seaboard Coastline | SC | 75 | 109 | 113 |
| North Tampa | NT | 74 | 103 | 112 |
| Northwest Tampa | NW | 60 | 98 | 101 |
| Tampa Heights | TH | 60 | 93 | 100 |
| Hillsborough Ave. | HA | 49 | 78 | 87 |
| West Tampa | WT | 15 | 33 | 43 |
| St. Joseph's | SJ | - | 18 | 31 |
| Seminole Heights | SH | 6 | 15 | 21 |
| Kirby Creek | KC | - | 11 | 23 |
| Sunshine Park | SP | 2 | 9 | 13 |
| Sulphur Springs | SS | 1 | 5 | 7 |
| Wellswood | WW | - | 5 | 8 |
| River Bend | RB | - | - | 4 |

## TABLE D-2. SUMMARY OF 1982 FLOODING COMPLAINTS BY MINOR DRAINAGE BASIN

| System Abbrv. | No. of complaints | % of complaints |
|---|---|---|
| SP | 36 | 19.5 |
| KC | 24 | 13.0 |
| WW | 22 | 11.9 |
| OG | 20 | 10.8 |
| HA | 17 | 9.2 |
| TH | 15 | 8.1 |
| WT | 12 | 6.5 |
| FH | 9 | 4.9 |
| RB | 8 | 4.3 |
| SJ, NW, SS | 5 each | 2.7 |
| NT | 3 | 1.6 |
| SC | 2 | 1.1 |
| DT, SH | 1 each | .5 |
| Total | 185 | 100 |

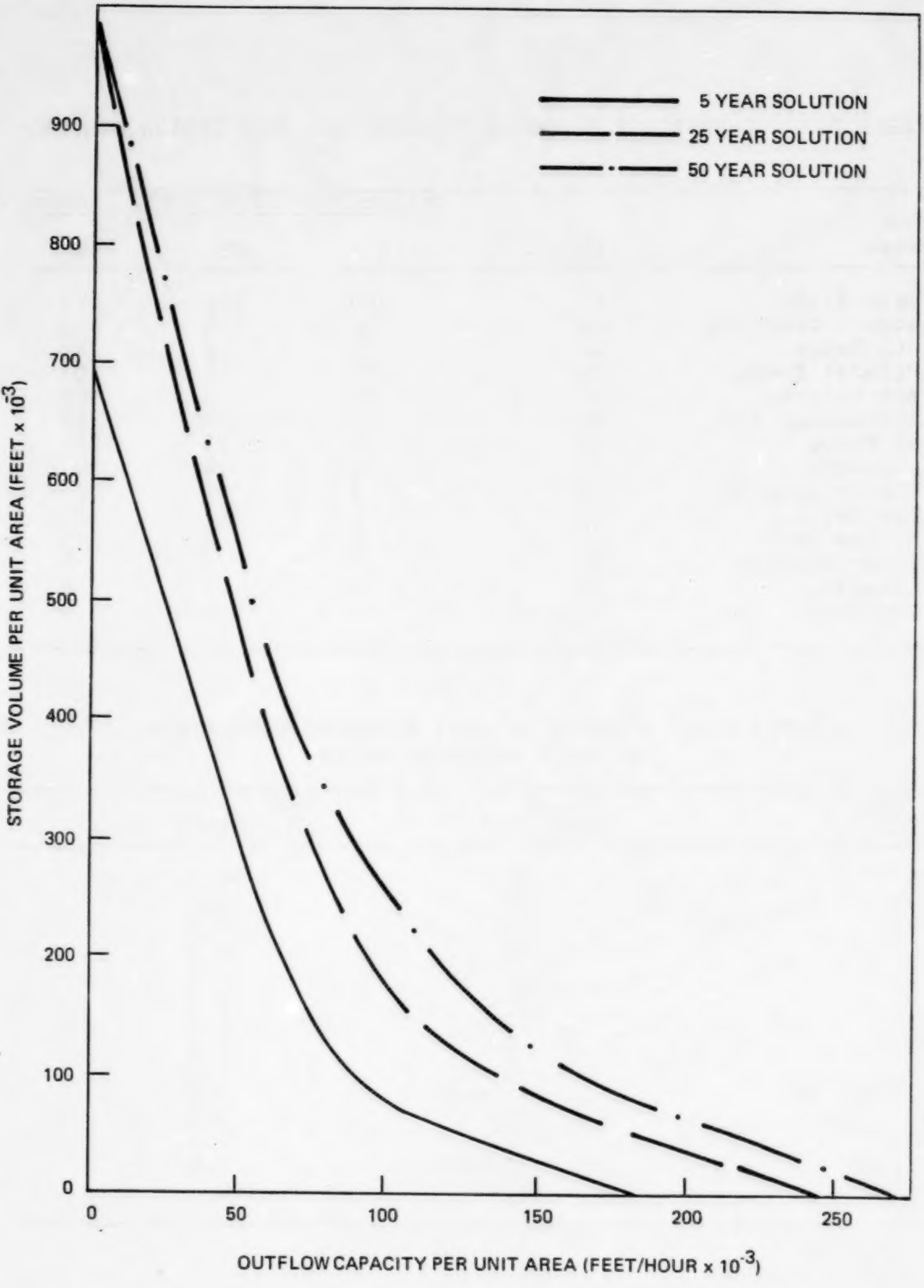

FIG. D-2 FLOOD SOLUTION CURVES FOR THE DESIGN STORM EVENTS

The derivation and use of these curves are described in detail in Chapter 2 of this study and illustrated in Chapter 5. Such use primarily entails defining the following two parameters for the major system:

$$\text{Storage capacity per unit are} = \frac{\text{Existing Storage Volume}}{\text{Effective Runoff Area}}$$

$$\text{Outflow Capacity per unit area} = \frac{\text{Existing Outflow Capacity}}{\text{Effective Runnoff Area}}$$

where Effective Runnoff Area = (Runoff Area x Runoff Coefficient). The Rcs used to estimate Effective Runoff Area should be those established in Phase II from analysis of extensive rainfall/runoff data. These are:

Commercial/Industrial Rc = 0.90

High Density Residential Rc = 0.68

Medium Density Residential Rc = 0.53

Low Density Residential Rc = 0.37

Institutional Rc = 0.31

Open/Natural Rc = 0.15

4. Develop Quality Solutions - The objective is to remove or detain stormwater load when possible and practical. This objective is satisfied by runoff reduction and increasing storage volume, but not by increased capacity.

5. Evaluate DER Stormwater Permit Effects - Runoff reduction and increased storage volume satisfy the State stormwater permit regulation. Increasing outflow capacity will,

in general, not satisfy the DER regulations. The removal rates of various stormwater controls if designed as required for the DER permit are given in Table D-3.

Detailed Planning Phase. The detailed planning phase involves development of the detailed Master Drainage Plan for the basin. Major design considerations, assuming all detailed drainage system data are available for the basin, are development of a design storm and the stormwater modeling analysis. These are explained in detail in the following paragraphs.

Design Storm Development - The Tampa NURP intensity-frequency-duration curves developed in Chapter 2 can be used. If required, the FDOT curves can also be used, although they are less conservative. A time interval of approximately 20 minutes should be used in order to capture realistic peak intensities. This interval could be adjusted based on site specific data.

The 5-year 8-hour storm with a maximum intensity of 4.5 inches/hour shown in Figure 5-4 at Volume I should generally be used as the design event. Designing new systems or improvements to existing systems in accordance with this event will provide an adequate level of protection, consistent with many other urban areas. However, if the budget can accommodate providing high value districts with more protection, this could be considered. It should be noted that the duration of this event is longer than the time of concentration ($t_c$) of the major systems that may be modeled with SWMM. This makes the relative response of different drainage areas independent of $t_c$.

## TABLE D-3. SUMMARY OF DER PERMIT EFFECTS ON STORMWATER FLOW AND LOAD REDUCTION

| Stormwater Permit Requirement | Flow Reduction (percent) | Load Reduction (percent) |
|---|---|---|
| Runoff retention with 72 hour drawdown | | |
| dry condition(1) | | |
| soluble pollutants | 74 | 74-82 |
| particulate matter | 74 | 74-97 |
| wet condition(2) | | |
| soluble pollutants | 25 | 25-48 |
| particulate matter | 25 | 25-93 |
| long-term average condition(3) | | |
| soluble pollutants | 62 | 62-74 |
| particulate matter | 62 | 62-96 |
| Ditches(4) | | |
| ditch | 100 | 100 |
| undercut ditch | 100 | 100 |
| Storm Sewer Laterals | 0 | 0 |

1. Separation time greater than 72 hours (typical dry season).
2. Separation time about 24 hours (typical wet season).
3. Assumes wet season condition for 25 percent of time (33 percent effective) and dry season for 75 percent of time (fully effective).
4. Pollutant removal assumed equivalent to hydraulic removal.

Stormwater Modeling Analysis - Implementation of the flood prevention requirements developed during preliminary planning using the general flooding solution should be simulated under design conditions with the SWMM. The hydraulic and quality coefficients developed during the Tampa NURP Study for use in SWMM are given in Appendix A. Using the SWMM enables storm sewer systems to be "fine tuned" and allows comparison of alternatives so that State stormwater permitting requirements are met. Ideally improvements to the existing system should be incorporated into the SWMM until it predicts no surcharging. SWMM ensures compatibility of existing and proposed systems as it models their integration in detail.

Operations and maintenance (O&M) requirements must also be considered in selection of a final plan for a drainage area. A detailed O&M discussion can be found in Appendix E of this manual.

Consideration of the relative costs of various implementation schemes can be estimated following guidelines such as those of Table D-4.

The quality impacts of the implementation practices can be evaluated based on the removal rates established for various flood control practices during Phase II (3) and presented in Table D-5.

Design and Construction. After all planning studies are completed and a recommended drainage plan has been developed, final design and specifications can be prepared for the drainage system. Most of the information required to perform the final design has been developed through SWMM modeling. This includes pipe, pond and ditch, sizes, slopes and locations. The necessary information to apply for a stormwater permit has also been generated. Other information needed for final design includes

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## TABLE D-4. COSTS OF STORMWATER METHODS

| Flood Control Option | Implementation practice | Capital unit costs ($) | Maintenance annual costs ($) |
|---|---|---|---|
| Outflow Capacity Expansion | Storm sewer laterals | 100/lin. ft.(1) | Not Available |
| | Storm sewer manholes | 814/each | Not Available |
| | Storm sewer inlets | 1,800 each | Not Avaialble |
| Runoff Reduction | Drain trenches | 3,170/drain trench(2) | 26.70/drain trench |
| | Ditch systems/swales | 5.69/lin. ft. | .08/lin. ft. |
| Storage Volume Enlargement | Detention/Retention Ponds | 25,000/acre(3) (land acquisition)<br>21,800 acre(4) (excavation)<br>2,900/acre(5) (fencing)<br>12,600/acre (sodding) | 136/acre (mowing) |

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1. Assumes a diameter of 54 inches.
2. Assumes 150 ft., City of Tampa uniform trench.
3. Based on appraisals made in River Grove subarea for a different study by a City approved appraiser.
4. Assumes 3 ft. of excavation.
5. Assumes average pond surface area of 3 acres.

## TABLE D-5. SUMMARY OF REMOVAL RATES FOR VARIOUS FLOOD CONTROL PRACTICES

| Flood Control Practice | Long-term hydraulic removal rate (% of inflow rate)(1) | Long-term pollutant removal rate (% of inflow load) |
|---|---|---|
| Drain trenches | 30 - 35 | 30 - 35 |
| Ditch systems - regular | 30 - 70 | 30 - 70 |
| Ditch systems - undercut | 50 - 70 | 50 - 70 |
| Retention/ Detention ponds | 20 - 95 | 0 - 30 (soluble pollutants)<br>0 - 90 (particulate matter) |
| Storm Sewers | 0 | 0 |

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1. The hydraulic removal rate for detention ponds is the percent reduction or attenuation of the peak inflow rate.

such things as soil borings, locations of existing utilities, and construction materials to be used. This information can be developed through standard City practices.

### Minor System Drainage Design

The minor system drainage design follows current City drainage design, which uses the Rational method. Only minor changes in use of this method are required. The primary charge is that the Rcs currently used can be replaced by those presented in the last section on major systems. In addition, the recommended major system guidelines to storm protection can be incorporated into minor system design. This applies to detention/retention ponds as well as storm sewers. Other minor design details are based on practices in use at Metcalf and Eddy, Inc. (4). Manning's n should be 0.015 for all RCP and 0.016 for concrete boxes. The minimum velocity for conduit flow should be 3.0 fps. Spacing between manholes on an 18 inch diameter lateral can be as much as 350 feet.

Quality considerations in minor system design are the same as those for major systems.

## Summary

In this Appendix, drainage system design methodologies have been described for both major and minor systems. This Appendix incorporates the results of the NURP study as well as other current design standards into the City's existing procedures. It also provides guidelines on definition of major and minor drainage systems.

# REFERENCES

1. City of Tampa, Drainage Design Criteria, Internal Memorandum, February, 1975.
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# APPENDIX E

# OPERATIONS AND MAINTENANCE

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# SECTION 1

## INTRODUCTION

The objective of this technical memorandum is to provide input to the City's Stormwater Management Plan on a methodology to review existing and proposed systems and establish an operations and maintenance program which considers the required repairs and replacement activities for optimal quantity and quality control. The approach utilized to accomplish this goal is to examine the overall O&M problem and the projected activity and service levels to determine whether the services being provided are consistent with the stated goals and objectives of the program. The evaluation and control mechanisms which have been developed by the Stormwater Management Division are evaluated, and finally, recommendations are presented for maintenance procedures for the stormwater management practices tested during Phase II.

The O&M Section is the largest of the groups in the Stormwater Management Division with approximately 98 positions and a FY 1983 budget of $2,531,929. The O&M Section is responsible for three major services which operate and maintain the drainage infrastructure for the City: ditch and pond maintenance, storm sewer repair and construction, and storm sewer cleaning and street sweeping.

The remainder of the technical memorandum is divided into five sections. Section 2 examines the O&M problem faced by the Stormwater Management Division in terms of known and quantifiable problems as well as the unknown problems which are difficult to quantify and plan for, but are related to relms of nature and politics. The third section of the memorandum examines the stated goals and objectives of the Division for each of the three service activities. Comments and observations concerning the appropriateness of the goals and objectives and proposed modifications are presented.

Activities and service levels are evaluated in Section 4 in terms of the services planned, the proposed operating budget for each of the services, the degree of goal attainment within each service, and finally, the impact of long-term projects on the O&M Section. The fifth section reviews the existing evaluation and control mechanisms which are employed by the O&M section and presents comments and observations regarding problems in the use of the existing systems and the suitability of these systems for future use.

Finally, Section 6 reviews the conclusions of the Phase II stormwater management practice testing program and recommends specific

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maintenance practices for these devices. These recommendations are based on specific testing results where possible, and include general suggestions for additional maintenance practices where tested. Data are either unavailable or inclusive. This section also contains recommendations for a continuing testing program to accumulate data which would support the future development of specific maintenance recommendations for the individual practices.

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## SECTION 2

## THE O&M PROBLEM

The size and scope of the O&M problem faced by the Stormwater Management Division is partially quantifiable and can be divided into known and unknown problems. The remainder of this section addresses these two categories of problems.

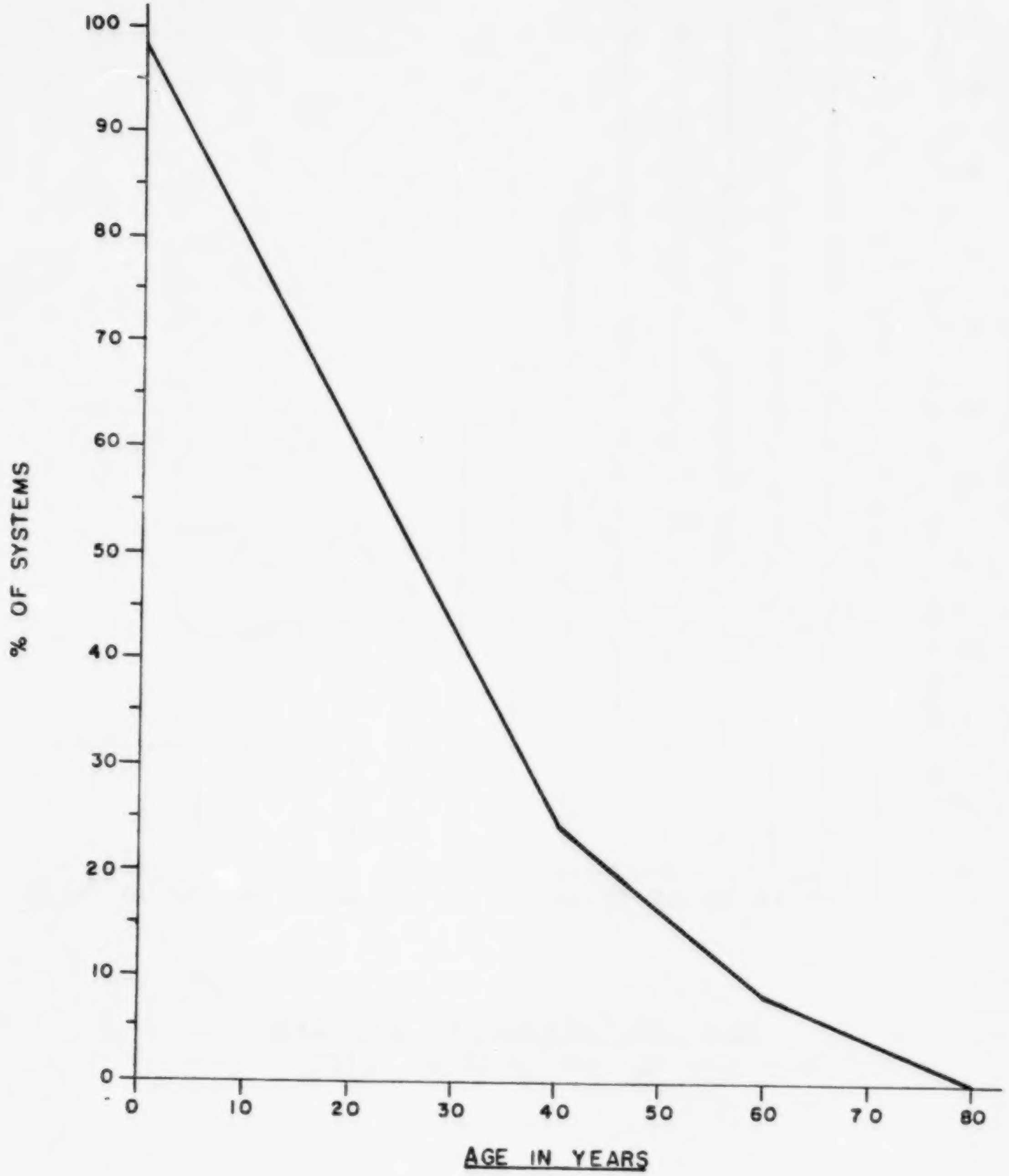
### Known Problems

The known problems are perhaps the easier of the two categories to deal with because they have already been identified and can be quantified and evaluated. Generally, the known aspects of the O&M problem deal with the physical inventory which the Department has maintained such as ditches, pipe systems, ponds, and the drainage aspects of the road network. The following brief table gives an indication of the extent and size of the O&M problem in Tampa:

| | |
|---|---|
| Ditches - Major | 26 miles |
| - Minor | 200 miles |
| Detention Ponds | 90 ponds |
| Stormwater Pump Stations | 30 stations |
| Pipes - Greater than 24 inches | 176 miles |
| - Up to 24 inches | 365 miles |
| Inlets | 21,200 units |
| Manholes | 10,600 units |
| Culverts | 7,700 culverts |
| Curb & Gutter | 1,226 miles |
| Streets - Residential | 978 miles |
| - Commercial | 330 miles |

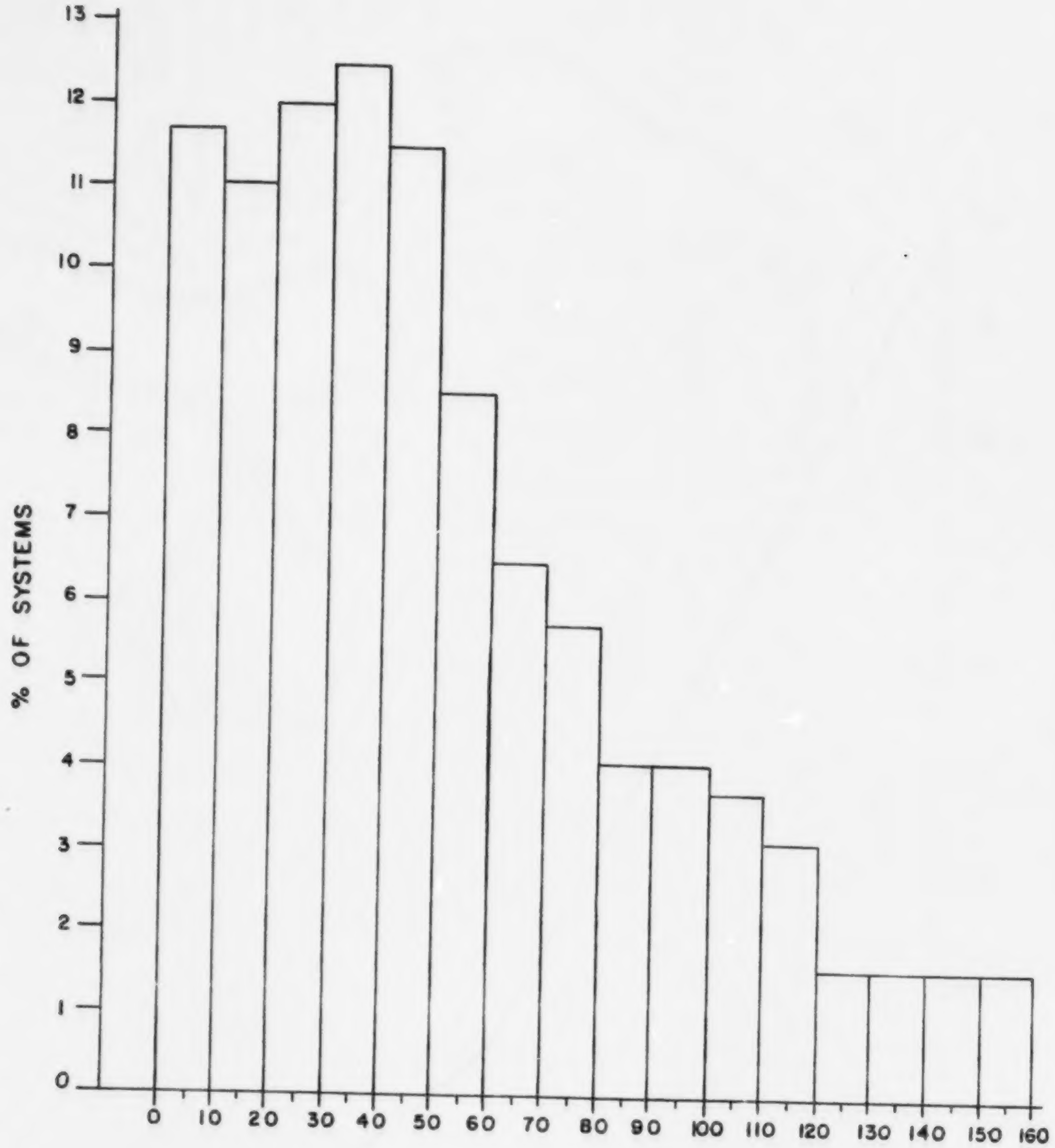
The drainage infrastructure in Tampa is wearing out faster than it is being replaced. The City has completed a detailed survey from which an aging profile and an estimate of the useful life of the pipe network has been developed and is shown in Figures 1 and 2. The replacement program for storm sewers is on a 385-year cycle but the weighted average of the life of all drainage systems in the City is 55 years.

The most recent Service Level Analysis document states that routine maintenance is funded at an adequate level but present assessments of field conditions suggest otherwise. If current funding levels were adequate, the City would not be experiencing the infrastructure problems which are alluded to throughout the Service Level Analysis document. Furthermore, although routine maintenance is currently be funded at an adequate level from a long-term perspective, it is not certain that the Stormwater Man-



AGE PROFILE

FIGURE I



AGE OF DRAINAGE SYSTEMS
AS % OF USEFUL LIFE

FIGURE 2

agement Division can adequately compete with other Citywide priorities in the future. This uncertainty, together with an essentially non-existent remedial maintenance program (replacement) and minimal capital improvement program, is leading the City to a point of recommending a separate funding source. This new source of funding will be based on service charges, thereby eliminating the Department's dependency on competing within the limited General Fund. Drainage Revenue Fund Feasibility studies were completed in May, 1983 and are presently awaiting action by the Department.

Unknown Problems

The second class problems, unknown problems, is much more difficult to deal with because it includes a number of factors which cannot be easily described and/or quantified. Many of the unknown problems are in the providence of nature and politics -- two areas which defy definitive rational approaches in planning methodology. Included in the unknown problems are: Meteorological variations, groundwater fluctuations, budget and funding availability, resolution of joint City and County drainage problems, and assessment of system-wide structural conditions.

Meteorological variability from month to month as well as year to year creates planning and operational problems which have to be dealt with on a daily basis as well as impeding normal operations such as pipe cleaning, ditch cleaning, and reconstruction activities. The intensity, volume and number of events can create flooding, washout, and cave-in problems which have to be dealt with immediately. Variations and the timing of the volume of rainfall events impacts the operation of ditches and detention ponds with the City.

Groundwater fluctuations acting either alone or in conjunction with meteorological variability create a different set of problems. Higher groundwater levels create continuous base flow in many of the larger ditches and, when combined with high-volume/-high-intensity rainfall events, can create system inundation and areal flooding problems. Another unknown aspect of high groundwater levels is its impact on system structural deterioration rates.

An important aspect of routine and emergency operations is the size of the annual budget and the timing of funding availability. One aspect which frustrates long-term stormwater planning activities is an unknown budget from year to year which causes the Department to either delay implementing certain programs which had been planned and/or fast-track projects which had not been planned but are undertaken because of unanticipated budget surpluses. In a similar fashion, the Capital Improvements Program for major projects also suffers from unknown funding levels on a year to year basis.

The City has a number of basins which either receive runoff or discharge from County systems. While drainage within these basins effects both City and County governmental units, the opportunity for a joint resolution of this problem is hindered by the different political and budgetary cycles which characterize the two units of government. These cycles adversely affect the ability of the Stormwater Management Division to study and solve problems with its counterpart in County government.

Finally, the Division does not have a good handle on the structural condition of its storm sewer pipe network. Assessments have been made and are utilized for planning purposes based upon limited sampling of the existing systems. While some efforts are underway to televise the stormwater sewer system through inter-departmental contracting with the Department of Sanitary Sewers, the limited availability of this equipment serves to compound the problem.

# SECTION 3

# GOALS AND OBJECTIVES

The Stormwater Management Division's O&M work program is divided into three different services: ditch maintenance, storm sewer repair and construction, and storm sewer cleaning and street cleaning. Each of these services have a broad and encompassing goal which sets the general direction of the work activities. The City has developed a number of objective/condition standards for each of these three goals as part of the Service Level Analysis procedure (See Section 5). These standards are formal, quantified statements which allow for specific measurement of productivity. The remainder of this section discusses the goal and objective/condition standards which have been developed for each of the three services of the Stormwater Management Division's O&M section.

## Ditch and Pond Maintenance

The first of the three services focuses on the maintenance of the existing ditch system and detention ponds within the City. The goal of this service is to maintain proper hydraulic flow line elevations and to eliminate all health and safety hazards in all open drainage systems. Twelve objective/condition standards have been developed to support the generalized statement of the goal. Eight of the standards are specific for ditches, three of the standards were developed for the detention ponds, and the twelfth standard addresses an unrelated area, City boat ramps.

The standards which were developed specifically for ditch systems, address the routine maintenance aspect such as mowing, silt accumulation, washout repair, and trash accumulation as well as the safety related issues of location of ditches in the safe recovery zone (the first eight feet of right-of-way measured from the edge of pavement) of major road segments and adequate access for maintenance. Standards developed specifically for ditches include:

- o No more than 25% of all large ditches and canals are to have grass and weeds higher than two 2 feet.
- o No more than 25% of all small ditches shall have grass or weeds higher than 1 foot.
- o No more than 10% of small ditches are to have more than 6 inches of silt.

- No more than 10% of large ditches or canals are to have more than 1 foot of silt.
- No more than 5% of all open drainage systems shall have a washout.
- Trash blocking flow through culverts or ditches shall be removed within 24 hours of notice.
- All major ditches shall have sufficient access for maintenance.
- No ditch shall be located within the safe recovery zone of any street segment of the road network in the collector category or higher.

Objective/condition standards which were developed for City owned detention ponds also include the routine maintenance item of mowing but also address the loss of hydraulic capacity and the need to fence unsafe ponds. Specific standards include:

- No more than 5% of retention ponds will have grass or weeds in dry areas higher than 18 inches.
- No more than 10% of all retention ponds shall function at less than 90% of design capacity.
- All unsafe retention ponds should be protected by fencing.

The last standard which has been developed for this service area addresses silt accumulation on City owned boat ramps, specifically:

- All City owned boat ramps shall have less than 2 inches of silt accumulation on the ramp.

## Storm Sewer Repair and Construction

The second service deals with the maintenance of the existing storm sewer system and includes the stormwater pump stations. The goal is to maintain proper hydraulic flow line and eliminate health and safety hazards related to inadequate drainage systems. Thirteen objective/condition standards have been developed to assist in the direction of work activities related at achieving this goal. Seven of the standards are related to repair and reconstruction of the existing system, three standards apply to new construction required to bring the existing system into compliance, and the remaining three standards are related to stormwater pumping systems.

The major work activity in this area is the repair and reconstruction of the existing sewer system in order to retain existing hydraulic capacity. Objectives prepared which are specific to repair and reconstruction include:

- Response to structural failure on any storm sewer or drainage appurtenance should not exceed 24 hours.
- No more than 25% of storm sewer system should be in less than good structural condition.
- No more than 5% of all curb or grate inlets should have cracked or damaged tops.
- No more than 10% of all culverts should be 25% or more off grade or less than 24 feet in length.
- No more than 5% of all culverts should be structurally defective.
- No more than 5% of all concrete curb and gutter, straight faced, and valley gutter sections should be defective. Defective is defined as having more than 2 inch deviation in the flow line of joints. No more than 25% of all concrete curb and gutter, straight faced curb, and valley gutter should be cracked, chipped or broken.
- No storm sewer system shall have a structure over any portion of its system unless that portion of the system is in excellent structural condition.

New construction is required throughout the City in order to bring the existing storm sewer system into compliance with objective standards. The associated work activities focus on installing new manholes where they are required for piping system access, construction of standard inlets, and construction of storm sewers in easements or public rights-of-way. Standards specific to this work activity include:

- Manhole spacing should not exceed 500 feet.
- No more than 20% of all curb inlets (46"x64") or grate inlets (Type E) should be non-standard. Substandard cleaning access creates high maintenance costs. Poor location creates traffic hazards.
- All storm sewers shall be located in dedicated easements or public rights-of-way.

The last related work activity in this section addresses the operation and maintenance of stormwater pump stations in low lying areas of the City. The standards which have been developed specifically for pump stations include:

- All stormwater pumping stations will be housed and adequately secured. All stormwater pumping stations will operate automatically. All stormwater pumping stations shall have a telemetry system capable of relaying operational information to a central location.
- All low areas of the City that are pumped regularly shall have an underground PVC force main discharge.
- Request for pumping at locations regularly flooded should be responded to within 3 hours.

Storm Sewer Cleaning and Street Sweeping

The last service is targeted at maintaining hydraulic capacity of the existing system. The goal is to maintain proper flow line elevations, satisfy water quality objectives, and provide aesthetically acceptable street gutters. Eleven objective/condition standards have been developed to support this broad goal.

Storm sewer cleaning is the more labor intensive consideration and is addressed by six specific standards. The focus of four of these standards is the accumulation of material in the pipe which reduces hydraulic capacity, one standard addresses field response to flooding complaints, and the sixth standard addresses the development of a standard for two new pollution abatement devices. These specific standards include:

- No more than 15% of all storm sewers within the City Limits should be 10% full of dirt, silt, and other debris.
- No more than 15% of all culverts should be 10% full of silt, and other debris.
- No more than 10% of inlets should be clogged to a depth greater than 50% of the diameter of the connecting pipe.
- All open drainage systems that outfall into a storm sewer (36") or greater shall be protected by a debris catching structure.

- Field investigations regarding citizens' complaints pertaining to flooding, due to drainage system blockages, should not exceed 3 hours; response to all other complaints regarding storm sewer maintenance should not exceed 72 hours (response refers to resolution of the problem).

- By May, 1983, institute a maintenance standard for open bottom inlets and drainfields related to pollution abatement.

The area of street sweeping is addressed by five objective/condition standards of which three focus on sweeping of commercial areas and different drainage basins, one focuses on residential sweeping upon citizen requests, and the last standard addresses the loss of hydraulic capacity in gutters due to blockage by deciduous leaf accumulation. More specifically:

- All commercial streets which drain into the Hillsborough River drainage should be swept twice a week by a vacuum sweeper.

- All commercial streets which drain into Hillsborough/McKay Bay should be swept twice a week by a vacuum sweeper.

- All commercial streets which drain into the Old Tampa Bay drainage basin should be swept once a week by a vacuum sweeper.

- Residential sweeping will be done from citizens' request, based on established need criteria. Response time will not exceed 15 working days for those segments requiring cleaning. No more than 50% of the vertical height of any gutter shall be blocked with debris.

Comments and Observations

The following comments, based upon review of the three goals and the thirty-six attended objective/condition standards, are offered for consideration by the City of Tampa:

1. The issue of water quality in detention ponds which are normally wet has not been addressed. The development and maintenance of a littoral shelf at the rim of the detention pond should serve to improve the quality of the stormwater passing through the detention pond and maintain or improve the quality of the water which is retained in the pond when it is not acting as a detention facility. Perhaps an additional goal should be developed along the lines of:

Major detention ponds which are normally wet shall have a littoral shelf constructed at the pond edge during normal reconstruction and/or maintenance activities to improve water quality. However, it must be recognized that the attainment of the water quality objective may be at the expense of mosquito control because rooted aquatic growth on the littoral shelf provides the perfect environment for mosquito propagation. This management decision will have to be made at Departmental levels.

2. One aspect of bad drainage design which results from past drainage design practice is the accumulation of large volumes of water in the gutter systems and on the street surfaces. As part of the scheduled reconstruction activities which are undertaken by the Department, these problem areas could be remedied on a prioritized basis. An additional goal should be included along the lines of: Gutters and/or street surfaces which carry stormwater flows in excess of 10 cubic feet per second and/or at velocities in excess of 3 feet per second shall have their drainage systems reconstructed to limit surface stormwater transport to either a maximum of 10 cubic feet per second prior to entry to an inlet, or, a maximum surface velocity of 3 feet per second before capture by an inlet.

3. Considering the problems which the O&M Section have experienced with grate inlets, it would seem reasonable to replace chronically clogged grate inlets with a standard curb inlet to eliminate the flooding problems which result from clogged grate inlets. A new goal might be: Replace grate inlets which chronically experience clogging and cause flooding with standard curb inlets.

4. The present standard design utilized by the City of Tampa for open bottom inlets has been shown by testing in Phase II to be an ineffective stormwater management practice for either quantity or quality. Dependent upon the results of the proposed testing of the proposed new open bottom inlet design, one of the following actions should be implemented:

    - In the event that the test results for the new design for the open bottom inlet prove effective, then a maintenance standard should be developed for this device.

    - In the event that testing of the new design continues to indicate ineffectiveness on the part of the device, then no development of a maintenance standard should be undertaken and the device should not be utilized in the City.

5. Should the testing of the revised open bottom inlet design prove effective, the O&M Section should consider utilizing open bottom inlets in lieu of standard inlets as part of their normal reconstruction program wherever the groundwater table will allow the installation of open bottom inlets. The proposed goal might be: Where groundwater levels permit, utilize an open bottom inlet as the standard design section in the reconstruction of existing stormwater systems.

6. Testing of other stormwater management practices during Phase II indicated that undercut ditches were effective in removing stormwater volume and pollutants. A maintenance standard should be developed for undercut ditches to enhance their function as a stormwater management practice. A proposed standard might be: By May, 1984, institute a maintenance standard for undercut ditches related to pollution abatement as opposed to hydraulic conveyance. Recent studies of ditch bottom permeability by the O&M Section indicate that some ditches develop, within six months of maintenance, a ditch bottom "crust" which has a tar-like consistency and is essentially impermeable. A small scale monitoring program should be implemented for a representative number of newly maintained ditches to determine the nature and extent of this phenomena prior to the adoption of the proposed standard.

7. With regard to the reconstruction activities associated with the movement of existing storm sewers and ditches from private property to the public right-of-way, a benefit analysis should be conducted to determine whether an easement or additional right-of-way can be obtained at cost equal to or lower than the proposed reconstruction. A goal to this effect might be: Evaluate the cost of acquiring additional right-of-way or drainage easements for existing systems that are located on private property that must be relocated in public easements or right-of-ways to determine whether the cost associated with reconstruction is less than the cost of land or easement acquisition.

8. In lieu of the amount of attention which is paid to removing silt and sediment from the existing pipes and ditches in the drainage system, it would seem prudent to investigate the feasibility of implementing an erosion control ordinance to prevent its deposition in the pipes and ditches. While the feasibility study for the implementation of an erosion control ordinance does not fall in the purvue of the O&M Section, this suggestion should be considered at Divisional levels due to the annual cost of cleaning ditches and pipes. Apparently the City presently has a form of an erosion con-

trol ordinance on its books but it is not being implemented. This management decision should be reviewed. The pertinent features of the ordinance can be incorporated in the proposed model drainage ordinance and implemented through the drainage review process.

9. The water quality impacts of street sweeping, while not tested in the Tampa Bay area, were tested nationally as part of the NURP Study. The conclusions at the national level are that the pollutants which are collected during street sweeping may or may not be a problem in the receiving water. While the City has documented the tons of street sweeping debris which are disposed of each year and has recently analyzed this dry particulate matter for content, no cause and effect relationship has been demonstrated between the removal of this material from street surfaces and the improvement of water quality. If no relationship can be found at the conclusion of the Receiving Water Study, it would not seem prudent to continue extensive sweeping of commercial basins on the basis of water quality. While the ongoing sweeping may be justified from a political perspective, based on the asthetics of clean streets and residential neighborhoods, it may not be feasible to continue street sweeping on the basis of water quality and the specific commercial sweeping standards may have to be either revised or deleted.

# SECTION 4

# ACTIVITY/SERVICE LEVEL EVALUATION

The evaluation of the activities undertaken in FY 1983 will be accomplished in four sections: Services planned, projected budget expenditures, goal attainment, and long-term projects. Two documents serve as the basis for this analysis and they include: FY 1983 Service Level Analysis (selected sections applicable to the Stormwater Management Division), and the Work Program and Budget for Fiscal Year 1983 (Form 601). The content of these documents is not presented in this memorandum but selected characteristics are utilized to support the discussion in the text.

## Services Planned

The three service units that make up the Stormwater Management Division's O&M Section are scheduled to be involved in forty-three distinct and quantifiable work activities during FY 1983. The forty-three activities which are contemplated are generated in an attempt to satisfy the objective/condition standards for each of the three service areas.

The FY 1983 Work Program and Budget contains an inventory of existing facilities which need to be operated and maintained and projects the annual work quantity within each activity which should be accomplished. While many of the annual work quantity units are not readily comparable with the inventory measure, (for example, ditch washout repair is inventoried in terms of ditch miles while the unit of measure for the annual work quantity is cubic yards) seventeen of the forty-three activities do allow a direct comparison. Table 1 presents these activities and describes the units of measurement, the annual work quantity projected, and the system inventory. Additionally, the last column indicates the percent of inventory accomplished which also represents the service frequency (for example, major ditch grading occurs on 25 percent of the inventory meaning that major ditches would be graded once every four years).

Table 1 indicates a disturbing characteristic in the work program which will have long-term ramifications: the piping components of the storm sewer systems are being seriously neglected. While the table indicates that both major and minor ditches are being routinely maintained and that street sweeping is efficiently accomplished, it also indicates that the major maintenance aspects of the pipe system such as necessary excavation and construction, reconstruction, slip lining, and large pipe cleaning are simply not being accomplished. The City's own assessment is that: (1) the drainage infrastructure is wearing out faster than

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## TABLE 1

## FY 1983 WORK PROGRAM

| | | Units | Annual Work Quantity | System Inventory | % of Inventory |
|---|---|---|---|---|---|
| Major Ditches: | Grading | miles | 64 | 26.0 | 25 |
| Small Ditches: | Grading | miles | 118 | 200 | 59 |
| | Mowing | miles | 710 | 200 | 355 |
| Chemical Spraying | | miles | 726 | 200 | 3.6 |
| Ponds: | Mowing | acres | 1,109 | 251 | 406 |
| | Cleaning | acres | 0.78 | 145 | 1 |
| Excavation & Construction: | Pipe | miles | 0.6 | 365 | 0 |
| | Inlets | structures | 13 | 10,600 | 0 |
| Reconstruction: | Storm Sewers | miles | 0.95 | 365 | 0 |
| | Slip Lining | miles | 0.30 | 365 | 0 |
| | Drainage Structures | structures | 537 | 10,600 | 5 |
| | Concrete Curb | miles | 0.50 | 1,226 | 0 |
| Street Sweeping: | Residential | miles | 4,449 | 978 | 455 |
| | Commercial | miles | 26,251 | 330 | 7,955 |
| Cleaning: | Culverts | each | 1,150 | 7,700 | 15 |
| | Large Pipes (D>24") | miles | 1.42 | 176 | 1 |
| | Small Pipes | miles | 34.09 | 365 | 9 |

it is being replaced, (2) the replacement program for storm sewers is on a 385-year cycle when the weighted average of the life of all drainage systems is 55 years, and (3) 13% of the existing drainage systems are beyond 100% of their useful life and another 11% are in the last 25% of their useful lives.

In order to reverse this trend and prevent the collapse of the drainage infrastructure, the City must be willing to expend substantially larger sums of money in the reconstruction, repair, and cleaning of the storm sewer pipe network. These activities should show a marked increase in annual work quantity and in the percent of inventory serviced each year.

## Budget

The O&M section's FY 1983 budget was $2,531,929 which represents approximately 94 man years of labor and $845,380 of equipment and material costs.

The ditch and pond maintenance service utilized 32.95% of the total O&M budget and 37.12% of the total labor. The majority of this budget (86.20%) was utilized in the maintenance of the 200 miles of minor ditches and the maintenance of major ditches and detention ponds each total about 2% of the resources allocated. The following table presents the allocation of the resources budgeted for ditch and pond maintenance in terms of manpower, total dollars, percent of the activity budget, and percent of the total division O&M budget.

| | Total Labor (man days) | Total Dollars Required | % of Service Budget | % of Section Budget |
|---|---|---|---|---|
| Major Ditches | 275 | $ 47,317 | 5.67 | 1.87 |
| Minor Ditches | 7,834 | 718,959 | 86.20 | 28.40 |
| Detention Ponds | 726 | 46,774 | 5.61 | 1.85 |
| Other | 244 | 21,045 | 2.52 | 0.83 |
| Total | 9,079 | $834,095 | 100.00 | 32.95 |

The budget allocated for the construction/reconstruction of storm sewers and stormwater pumping activities made up nearly half of the total Division budget. The resources allocated for this service were $1,130,977 which represents 44.68% of the total Section operating budget and 39.62% of the total Section labor for FY 1983. Approximately half of these resources were utilized in the repair and reconstruction of the existing storm sewer system which, as previously shown, had impact on the overall problem of less than 1%. New construction for the storm sewer system and pumping activities each accounted for approximately 20% of the available resources. The allocation of budget resources is shown on the following table:

| | Total Labor (man days) | Total Dollars Required | % of Service Budget | % of Section Budget |
|---|---|---|---|---|
| New Construction | 1,862 | $ 230,041 | 20.34 | 9.09 |
| Repair/Reconstruction | 5,984 | 585,454 | 51.77 | 23.13 |
| Pumping Activities | 839 | 240,916 | 21.30 | 9.52 |
| Other | 1,004 | 74,566 | 6.59 | 2.95 |
| Total | 9,689 | $1,130,977 | 100.00 | 44.68 |

The last service, storm sewer cleaning and street sweeping, received the smallest budget of the three operating units. The allocated resources of $566,220 represents only 22.37% of the total Section budget and 23.26% of the total Section manpower allocation. Dollars within this service unit were allocated approximately equally between street sweeping and pipe cleaning with street sweeping receiving about 9% of the total service budget. The allocation of the budgeted resources to the individual activities in this service unit are shown on the following table:

| | Total Labor (man days) | Total Dollars Required | % of Service Budget | % of Section Budget |
|---|---|---|---|---|
| Street Sweeping | 2,354 | $300,646 | 53.10 | 11.88 |
| Conveyance Cleaning | 3,172 | 249,735 | 44.11 | 9.87 |
| Other | 162 | 15,839 | 2.79 | 0.63 |
| Total | 5,688 | $566,220 | 100.00 | 22.37 |

The following observations and comments regarding budgetary allocation are offered for consideration by the City of Tampa:

1. Comparison of the productivity in terms of major pipes in the drainage network and the budgetary expenditure in this activity indicates the need for a very significant increase in funding in this work activity. Allowing the current 385-year replacement cycle and a corresponding repair/reconstruction budget allocation of $575,000 indicates that the

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cost of repair on this system (in 1982 dollars) is $221,375,000 which, if simply allocated to the estimated service life in the systems of 55 years, would suggest that a minimum expenditure of current dollars of $4,025,000 is required in the repair/reconstruction activities alone to maintain the drainage infrastructure.

2. Given the severity of silt and sediment accumulation in both major and minor pipes within the City's drainage system and the projected service frequencies, (large pipes: once per 100 years, small pipes: once per 11 years) it would seem that the priorities for this activity should be increased at the expense of other activities (for example, street sweeping). Residents will normally tolerate less frequently swept streets more willingly than they will flooding due to clogged storm sewers.

Goal Attainment

Another technique available to analyze the proposed work program and budget is to evaluate the frequency that goals have been attained. FY 1983 data is not available for evaluation but FY 1982 data, which was used in development of the FY 1983 service level analysis, is available and has been reviewed. For any objective/condition standard there are four possibilities which exist for assessment which include: over achieved, achieved, missed, and unknown. Over achievement indicates that the budget as applied resulted in a work effort superior to that required by the condition standard (19% of all curb or grate inlets were non-standard while the objective standard was no more than 20%). Achievement means that the actual production level and the targeted level were equal. Missing the standard indicates that the actual achievement of the measured work activity was below the targeted level. And finally, unknown indicates that information was unavailable on either the target or the production and it was impossible to assess whether the standard had been achieved.

The assessments contained in the Service Level Analysis indicate of the 36 condition standards, three (8%) were over achieved, seven (19%) were achieved, eighteen (50%) were missed, and eight (22%) were unknown. The assessment of the 1982 work program and budget indicates that of the 28 measured standards, eighteen (64%) missed the target level. The goal achievement results for each of the three services are presented in the following table:

| | Ditch and Pond Maintenance | Storm Sewer Repair and Construction | Storm Sewer Cleaning and Street Sweeping |
|---|---|---|---|
| Over Achieved | 2 | 1 | 0 |
| Achieved | 2 | 1 | 4 |
| Missed | 7 | 6 | 5 |
| Unknown | 1 | 5 | 2 |
| TOTAL | 12 | 13 | 11 |

These findings for achievement of goal levels indicate that one of the two following conclusions is valid:

- The overall output of the work program must be increased, through either increases in productivity or increases in funding, in order to achieve the target levels.
- The target levels are unrealistic in light of available funding and administrative constraints and should be revised.

## Long Term Projects

The last method used in the analysis of the work program and budget is an evaluation of the nature and number of long-term projects. Long-term projects indicate two things: the need for capital improvements funding in projects which are being delayed or accomplished at very slow rates due to insufficient funding levels or low prioritization.

Evaluation of the long-term projects for the ditch and pond maintenance service indicates two areas for concern. The first area is pond maintenance for detention ponds which have less than 90% of their design storage capacity and/or are unfenced. Both aspects of ponds have been relegated to minor Capital Improvement Fund projects which are in need of funding. The second area of concern relates to equipment needs in the areas of ditch mowing and ditch grading. The additional equipment would provide for greater unit output and increase the service frequencies.

The needs and alternative assessment for the storm sewer repair and construction service indicate a number of long-term projects which are cause for concern. Not mentioned in the assessment is the 385-year cycle for storm sewer replacement which is a serious cause for concern. Additionally, the 24-year program for pipe access through manhole construction, the 20-year proposed program for adjusting grate and/or length of driveway culverts, and, the 9-year program currently underway to reconstruct non-standard inlets, are all indicators of the serious piping system problems which exist in the City. Additionally, the need to acquire easements for the storm sewer pumping program and the need of additional pump stations and pumps indicates a serious flooding prevention need. Overall, as the City is well aware, this area needs serious attention in all future budgeting cycles.

The final service, storm sewer cleaning and street sweeping, does not appear to have any ongoing long term projects which are cause for concern. The service levels summary indicates that with the acquisition of two additional sweepers during FY 1983, that the majority of objectives which now are being missed in street sweeping should be realized.

# SECTION 5

# EVALUATION AND CONTROL MECHANISMS

This section of the technical memorandum presents existing methods which are utilized to evaluate the accomplishments and productivity of the O&M Section and to prepare the O&M budget for the following year. Comments and observations are presented based upon this review.

## Existing Methods

In 1978 the Department of Public Works implemented a new work management system to improve the delivery of services to the public. The implementation of this new system required that work activities be identified and that standards be developed for each of these activities. A great many positive benefits accrued as the result of the development of this system, including:

- Organizational communication increased due to the development of a common language between the individual sections of the Department.
- Productivity increased dramatically because of new work methods, new equipment and improved communications.
- Budgeting procedures became more meaningful because work could be planned and service levels developed for the budgeting period.

From an operational standpoint, services could be delivered based on a fixed service level that was tied to a fiscal year budget target. The operating units in the O&M Section rapidly evolved from high-expense, labor-intensive work crews to more equipment-intensive and more efficient work crews. Reliance solely on the work management system for budget development was not sufficient. A Citywide resource allocation mechanism was developed in 1981 during the preparation of the FY82 budget. Coupled with the work management system was a new process called Service Level Analysis which, when used with the appropriate modifications, is applicable to all Divisional Units. The process is applicable to all types of expenditure requests including:

- Current operations (maintaining existing service levels).
- New services to be performed or increased in current service levels.

- Replacement of major capital assets.

A Service Level Analysis process, in its application, analyzes and determines the total Citywide service needs. It consists of the following five key steps:

1. Preparation of a work plan for each operating unit of the division.
2. Development of objectives and standards for each work activity.
3. Assessment of physical conditions and productivity for each unit identified in the work plan.
4. Analysis of the productivity, manpower, and equipment needs required to meet established service levels.
5. Development of recommendations and prioritization of budget requests.

The initial step involves the development of a work program with wide participation from all levels of management within the division. At this point, it is necessary to emphasize the two most important components of the system -- physical inventory and level of service statements.

The accurate development of a physical inventory involves a fairly straight forward approach, but can be time consuming and costly. The inventory should not only relate to a particular feature to be maintained, but should be broken down into its basic components upon which an optimal maintenance activity can be performed. An example is the classification of ditches into classes that can be maintained by the most productive work method (hydraulic excavator, ditch master, dragline, or manual maintenance by crews).

The establishment of service levels is not quite as straight forward. The level of service is the component that brings together the work effort and the overall program objective. The established service levels are realistic and reflect the desire to provide service at a level up to the specified standard. Service levels for the Stormwater Management Division have been established by experienced supervisors, engineering standards, and other generally accepted criteria. The service level of a single activity or a group of related activities (ditch maintenance = ditch mowing + ditch grading + herbicide application) comprises a service objective that relates to the overall community needs.

The development of objectives and standards for each work activity is the second key step. The objectives and standards developed by the City of Tampa are realistic and relate to specific service goals. These objectives and standards provide a basis for determining the need for specific services, studying priorities, appropriation of funds, and can readily be translated into specific work activities. The requirement of establishing formal quantified objectives or standards is based on the premise that the allocation of City funds should be directed toward obtaining specific measureable results. Goals to be achieved are general, timeless, and non specific whereas objectives are definable, measureable, and clear.

The O&M Section has established thirty-six specific objective/condition standards which have been divided into three major work management units that include:

- Ditch maintenance (twelve standards).
- Storm sewer repair and construction (thirteen standards).
- Storm sewer cleaning and street sweeping (eleven standards).

An example of a goal and objective/condition standard for the Ditch Maintenance work management unit is:

| | |
|---|---|
| Goal: | To maintain proper hydraulic flow lines and eliminate health and safety hazards: |
| Objective: | No more than 15% of large ditches are to have more than one foot of silt accumulation above the established flow line. |

The third step is the conditions assessment. Each of the work management units in the O&M Section assesses the Citywide condition of their facilities and other items in their assigned area of responsibility. This is done for each activity identified in the work plan and the assessment requires a thorough understanding of the facility inventory. Conditions data is obtained by surveys, statistical sampling, work logs, and from other reliable data sources. An example of conditions assessment data for large ditch maintenance based on the example objective/conditions standard was gathered by random sampling (since it was not practical to survey all ninety six miles of major ditches in the city in a short time frame) and the assessment statement prepared stated:

Conditions: 16% of all large ditches had more than one foot of silt accumulation above the established hydraulic flow line (standard condition: 15%).

The fourth step is a needs analysis which compares the conditions assessment against the objective/condition standard and indicates the potential need to alter the work program. Changes in service levels are documented at this step to determine:

- The adequacy of current operating levels.
- The need to ad new services or increase current service levels.
- Overall replacement needs for major capital facilities.

The needs are, in reality, those changes to the short-range budget or work program that are necessary to satisfy the overall program objectives -- the long-range need. Determination of final needs requires some objective evaluation and may require strategy decisions by the management of the Division. In the example of the large ditch maintenance, the Staff reviewed past short-range work programs and determined that major ditch grading was not performed as a routine activity until recently and that the ditch grading service level had been increased in the previous budgets. The conclusion was that the current service level was adequate and the following statement is an example of the needs assessment:

Needs: Silting in large ditches is greater than the proposed standard. Because of recent increases in service levels, conditions will approach the established standard within two years. No change recommended.

Finally, after completing the first four key steps for each activity, work program recommendations are summarized and prioritized for presentation to the Mayor and the Executive Staff. This method provides a diversified forum to rationally develop work programs and companion budgets which include a sequential review that provides many beneficial side effects.

Comments and Observations

Evaluation of goal attainment, previously discussed in Section III, indicates that for the overall program, eight of the thirty six objective/condition standards (22%) could not be assessed because data was not available which could be evaluated to determine whether the goal had been obtained or not. An important aspect of the Service Level Analysis procedure is the setting of budget requirements based on performance. It is difficult to establish appropriate budgetary levels when productivity and achievement levels cannot be assessed due to lack of data. Therefore, time and resources should be allocated for the purposes of data collection to assist in the assessment of productivity and achievement levels. An adequate data base is an important aspect of the implemented procedures.

An inherent problem with the Service Level Analysis procedure when utilized with the budgeting system, is the time lags between the assessment of productivity for one year and the development of the budget for the following year. For example, the FY 1984 Service Level Analysis (SLA) contains no productivity or activity achievement data for FY 1983 due to the time frame in which the SLA and the budget preparations are accomplished. The only data available in the FY 1984 SLA is FY 1981 and FY 1982 productivity data. It would be beneficial to the Department and probably to the City in general, if the time lag between the assessment of productivity and activity levels and the establishment of budgetary levels were reduced.

The establishment of drainage as an enterprise fund with its own revenue sources will provide for increased opportunities to accomplish necessary O&M functions but will also necessitate the expansion of staff and the motor pool. This expansion will place additional demands on the evaluation and control mechanisms which are in place but the SLA is functionally sound and should persevere.

A mechanism should be developed for coordination with the Division between the O&M Section and the Planning and Design Sections. This coordination would allow for the passing of information in two directions and would benefit all Sections. Information obtained in the field through adverse experiences and hard labor can be passed to the Design and Planning Sections which would benefit their procedures and provide a more "hands-on" basis for their activities. In a similar fashion, activities which are to be undertaken by the Planning and Design Sections can be discussed with the O&M Section to mutually benefit all groups.

# SECTION 6

## RECOMMENDED O&M PROCEDURES

This last section of the technical memorandum addresses the recommended procedures for maintenance of the stormwater management practices which were tested during Phase II of the Tampa NURP Study. Devices which were tested included open bottom inlets, drain trenches, ditches and swales, and ponds. The recommended maintenance practices will be based, where possible, on specific findings of the Phase II studies. Additionally, a discussion of street sweeping is presented which has its basis in the nationwide findings of the NURP Program.

### Street Sweeping

Briefly, the conclusion of the studies which evaluated street sweeping as a pollution abatement measure on a nationwide basis as part of the NURP Program indicated that, depending on the location and the current condition of the receiving water, street sweeping may or may not be an effective pollution abatement practice. Clearly, the nationwide findings do not have any meaning for the City of Tampa.

A companion study to the Tampa NURP Study, the Receiving Water Study, has been evaluating the water quality behavior of the Lower Hillsborough River in response to stormwater inputs. The basis of this study has been synoptic sampling coupled with dynamic simulation of river water quality. Hopefully, this study will be able to develop a clear cause and effect relationship between the total pollutant loading entering the river and its resultant water quality reactions. Comparison of the necessary load reductions to achieve suitable water quality with the documented pollutant loads which are being removed by the current street sweeping program may indicate the relative beneficial impact of the street sweeping program.

Unfortunately, the present state of knowledge in Tampa concerning the impact of street sweeping on receiving water quality is not adequate as a basis for a recommendation for modifications to the existing street sweeping program. No recommendations are offered but the findings of the Receiving Water Study due in December, 1983, may indicate necessary changes in current practices.

### Open Bottom Inlets

The use of open bottom inlets as stormwater management practices for hydraulic peak attenuation and pollutant load reduction is relatively new in the City of Tampa. As such, available data on the operation and maintenance requirements of these devices is relatively unknown.

Field examination of existing open bottom inlets in the Sulphur Springs area indicated that the majority of the inlets have been adversely impacted by extensive accumulation of sediment and debris in the interior gravel pack. Hydraulic testing of three open bottom inlets during Phase II indicated that the hydraulic extraction capability of these devices was limited to the volume associated with the inner gravel pack. Apparently, the manner in which the open bottom inlets were constructed was such that silt accumulation in the interior gravel pack prevented stormwater from entering the void space of the exterior gravel pack.

The extensive accumulation of sediment and debris in the interior portion of the open bottom inlet suggests that sediment control is important for the device to function effectively. The obvious approach is to maintain these devices on a frequency which would prevent the accumulation of silt and sediment in the interior gravel pack and allow the device to function as intended. An alternative point of view would be to implement an erosion control ordinance to effectively reduce the generation rate of silt and sediment and thereby reduce the maintenance frequency.

Available data does not provide an adequate basis for making specific maintenance recommendations. Additionally, recommendations have been made for the modifications of the standard design for open bottom inlets and for a subsequent testing program. More data is required before specific maintenance recommendations can be prepared. It is recommended that, as part of the testing program for the revised open bottom inlets, that the inlets being tested be monitored on a bi-weekly basis to determine the rate of sediment accumulation in the interior gravel pack. This information could then be used in the preparation of specific maintenance recommendations for cleaning of the interior gravel pack in order to insure hydraulic efficiency.

As an interim measure, it is recommended that open bottom inlets be cleaned twice yearly. The recommended method of cleaning would be to remove all gravel in the interior gravel pack to the point of the filter fabric, replacement of the filter fabric, the subsequent covering of the new filter fabric with clean river gravel to the original levels in the interior gravel pack. This interim procedure should be revised based on the findings of the testing program for the revised open bottom inlet design.

## Drain Trench

As with the case of the open bottom inlets, the use of drain trenches for hydraulic attenuation and pollutant load reduction is relatively new in the City of Tampa. Available data for drain trenches is also limited.

The testing of drain trenches during Phase II of the Tampa NURP Study indicated that the drain trench was an effective method for removing stormwater volume and its pollutant load. However, no data was collected during this test program which indicated the rate of sediment accumulation in the device. Preliminary recommendations by Metcalf & Eddy, Inc. indicate that drain trenches should be maintained on a twice yearly basis by a Jetvactor.

Given the lack of available data on rate of sediment accumulation in the lateral pipe for the drain trench, it is recommended that the City select one or two trenches and monitor the rate of sediment accumulation in the pipes on a bi-weekly basis for a six month period to determine whether the recommended frequency for maintenance of twice a year is justified.

## Ditches and Swales

The extensive accumulation of sediment in existing ditches and swales has been documented by the City for a number of years. A municipal ditch cleaning frequency of once every five years is generally accepted. The City's Service Level Analysis indicates that major ditches have been graded on the frequency of once in four years and that small ditches have been graded on the frequency of once in 1.7 years.

One advantage of ditches as opposed to swales is the opportunity to undercut existing ditch systems. Two specific benefits accrue when ditches are undercut (graded below their normal invert-to-invert slopes). First, testing during Phase II indicated that undercut ditches were able to extract more water and thereby remove more of the pollutant load from the stormwater. The implications of this finding on a systemwide basis are obvious. The second and more subtle aspect of undercutting ditches is that the process of undercutting simplifies the determination of when the ditches should be regrated. For example, if a ditch is undercut by 1 foot (which corresponds to the 1 foot silt accumulation standard) when the sediment is removed, the maintenance crews can easily tell when it is time to regrate the ditch because the elevation of the ditch in the downstream end will have approached the invert elevation of the downstream culvert. It is recommended that, for considerations of hydraulic attenuation and pollutant removal, that the City consider undercutting all existing ditch systems where groundwater levels and public health and safety considerations permit.

## Ponds

The last management practice is the most difficult from the point of view of developing specific maintenance recommendations. The highly variable size, depth, and design of ponds within the City essentially preclude the development of uniformly applicable maintenance recommendations. The following paragraphs contain general observations and some recommendations for the maintenance of ponds which are specific to certain classes of ponds but are not generally applicable to all ponds.

Major detention ponds which are normally wet and have significant depth should be maintained and/or reconstructed with a littoral shelf. The presence of the littoral shelf could improve water quality by virtue of natural processes which utilize the rooted aquatic vegetation on the shelf to filter the water passing through the shelf and remove nutrients by the process of assimilation. Additionally, presence of the littoral shelf is aesthetically pleasing to many people as it provides a scenic vista.

Most ponds throughout the City which are normally wet, present the potential of functioning as disease vectors because they present an ideal habitat for mosquito breeding. These ponds should be sprayed periodically with State approved chemicals to prevent the breeding and propagation of mosquitos (by Hillsborough County Mosquito Control personnel).

In the case of ponds which normally drain dry, the City should give consideration to modifying their current sediment removal practices. Where groundwater conditions permit, ponds should be excavated to a level below their design bottoms while the excavation equipment is on site. This practice would provide two distinct benefits. The first benefit, assuming a constant sediment accumulation rate, would be a reduced frequency of sediment removal due to the initial over-excavation of the pond. The second benefit would be reduction in stormwater system peak discharge rates due to the increased capacity in the pond to store stormwater. This benefit would gradually diminish as sediment accumulated in the pond and decreased the storage value.

The final aspect of pond maintenance to be considered is the actual modification of the pond design during the sediment removal and reconstruction process. As part of Phase III of the Tampa NURP Study, modified design criteria have been proposed for ponds within the City. These criteria allow for modification of the side slopes of a pond, dependent upon soil characteristics, for fenced ponds. The opportunity exists for the City to reconstruct ponds with steeper side slopes and gain storage volume during the reconstruction process as long as the steeper banks are stabilized and will not cause loss of volume due to erosion.

This option should be considered seriously by the Division when planning minor City Improvement Program projects.

# APPENDIX F

# LONG-TERM RIVER MONITORING

## General

This Appendix reviews and comments on the City's ongoing receiving water monitoring program. The intent is to develop a monitoring program to provide lower Hillsborough River water quality data which is of maximum benefit to the City of Tampa. The Receiving Water Study (1) has shown that stormwater runoff is a significant source of coliform bacteria and some metals in this River estuary.

A long-term monitoring program should provide on-going information on River water quality characteristics that is cost-effective and will allow for analysis of water quality trends in the future. Various data collection approaches that have been used in the past as well as new approaches implemented during the Receiving Water Study (1) may be included in long-term River quality monitoring. A discussion of various data collection alternatives, their advantages and disadvantages, as well as suggestions for improving data collection programs is presented in this Appendix.

The types of data collection surveys to be reviewed are the background quarterly surveys, continuous data, synoptic surveys, and sediment data. Available data from other sources are also discussed.

## Quarterly Data Collection

Quarterly background surveys are currently conducted by the City of Tampa. These were intended to provide data on any long-term trends in River water quality. The disadvantage of this type of data collection is that water quality conditions in the lower Hillsborough River are continually changing depending on freshwater releases from the Reservoir and on climatic conditions. Analysis of long-term trends, as demonstrated during Phase I of the Tampa NURP Study (2), is difficult because River water quality is so dependent on the variability of these conditions. This disadvantage can be overcome by collection of data during specific River conditions, as described below.

Background water quality data are needed to evaluate trends in River quality. The quarterly program is well established and cost-effective as an on-going monitoring program. The continuation of the program would be beneficial to the City. The following suggestions are made to improve data completeness, presentation, and ease of analysis:

1. Water quality conditions in the lower Hillsborough River are highly dependent on freshwater flow releases from the Reservoir. Therefore, it is proposed to conduct each quarterly survey during a specific River condition. It is desirable to perform data collection after several weeks of very low release and another during a period of high release. The two additional surveys could be performed during an average

freshwater release and after a storm event. To indicate the worst case storm event impact, the storm event survey should be conducted during dry weather. Over several years this type of data could be analyzed for long-term River behavior under the specific conditions measured; and changes in River water quality could be observed.

2. Include the freshwater discharge from the Reservoir and Sulphur Springs on the quarterly summary sheets. This will provide information on background conditions and assist in data interpretation. The number of days since the last rainfall event with 0.1 inches of rainfall or more should also be provided.
3. Increase the number of in-situ measurements to at least 5 vertical points. Surface and bottom samples for BOD and other parameters are sufficient. However, salinity and dissolved oxygen may vary significantly based on freshwater flow conditions. Such measurements are useful to further the understanding of River processes and do not require excessive recording time.
4. Add in-situ profiling of River velocity, also at least five vertical points, to provide data on this important parameter.
5. Include chlorophyll a and turbidity measurements in the quarterly data collection. These will provide long-term information on algal activity and water

clarity as they relate to freshwater releases. This will assist in relating River conditions to water quality criteria.

6. Take a sample of the Reservoir water release, to identify River boundary quality input.
7. Current measurement station locations should be modified to include the four NURP stations.

## Continuous Data

This type of data collection provides important information on time series (one hour or less) variation of parameters sensitive to tidal fluctuation, such as salinity, dissolved oxygen and temperature. Depending on the duration of a continuous data program, long-term water quality variations can also be observed based on other processes such as freshwater releases from the Reservoir.

During the NURP Study, in a cooperative program with the USGS, four continuous recording gages were in place for 15 months at Platt Street, Columbus Ave., Sligh Ave. and 22nd Street. The City has cut the program back to two meters. If additional continuous data programs are undertaken it is suggested that several meters be installed at one station to measure surface, mid-depth and bottom (and more vertical points if possible) so as to provide further information on vertical variations of salinity and dissolved oxygen. If the number of meters is limited, it may be useful to rotate these meters between stations. The four stations used during the NURP study were well-suited to identify signficant longitudinal differences.

### Synoptic Surveys

Synoptic surveys provide data on water quality conditions over a short-term period (one to three days). While they are costly to undertake, specific needs may justify them. The synoptic surveys performed during the Receiving Water Study reflected a variety of River conditions. Data collected during these surveys should be of value for many years to come. It is suggested that in the future, if significant changes are implemented (for example, after implementation of several drainage basin Master Plans), another set of synoptic surveys be performed to monitor any improvements in the River water quality. Future synoptic surveys should include a station immediately below the Tampa Dam to provide better upstream water quality boundary conditions for water quality analysis and future model simulations.

### Sediment Quality Data

Evaluation of sediment quality also provides information for long-term trend analyses. Sediment quality data should be obtained twice yearly, during both low and high freshwater flows since bottom conditions are influenced by freshwater flow. In addition to the parameters currently analyzed, volatile content, organic carbon content, copper, lead and zinc are useful indicators of bottom conditions and should be collected and analyzed routinely.

Data From Other Sources

The following data, available from other agencies, should be obtained routinely and kept on file by the City:

1. USGS freshwater flow at the Hillsborough Reservoir dam and Sulphur Springs. Note that the daily summaries would be adequate for most purposes. The digitized data is not considered necessary.
2. USGS routine water quality sampling of the Hillsborough River and Sulphur Springs.
3. HCEPC routine water quality sampling.

These data sources may be used to supplement ongoing programs, and aid in interpretation of data collected by the City.

Summary

The quarterly water quality data collection as well as sediment programs are adequate at the present time for the continuation of monitoring in the River. The suggestions that have been outlined for these programs will provide better information on the background conditions in the River and therefore lead to a better understanding of the data collected. The other more detailed data collection programs are not considered necessary at the present time. Their recent undertaking has provided information on estuarine behavior that is not likely to change significantly unless specific River management alternatives (i.e. tide barriers, dredging) are implemented.

## REFERENCES

1. Metcalf & Eddy, Inc., Impact of Stormwater on the Lower Hillsborough River, Tampa Nationwide Urban Runoff Program, October, 1983.

2. Metcalf & Eddy, Inc., Phase I Receiving Water Study, Tampa Nationwide Urban Runoff Program, December, 1981.

# APPENDIX G

# LONG-TERM RAINFALL/RUNOFF MONITORING

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# SECTION 1

# INTRODUCTION

The following technical memorandum addresses the need for long-term monitoring in Tampa and examines the City's existing monitoring network. The goal of this task is to develop a monitoring network to provide stormwater and receiving water flow and water quality data for the City to update and evaluate the Stormwater Management Plan. Metcalf & Eddy, Inc. is responsible for the receiving water aspects of this task and Priede-Sedgwick, Inc. is responsible for the land-based monitoring activities.

The Stormwater Management Division presently operates a land-based monitoring network throughout the City of Tampa. The existing network consists of 3 stream flow monitoring sites, 6 recording rainfall stations, 10 pond water level evaluation monitoring sites, and 89 groundwater monitoring wells.

Generally speaking, the groundwater monitoring wells and pond elevation sites are manually read as part of a data collection route on a monthly basis. Rainfall and stream flow data are collected mechanically on analog devices and the records of these instruments are reduced by manual means. Recently, the descriptor data for each of these 108 stations has been entered into the City's data base management system.

All daily values from the streamflow and rainfall networks are input into this system and can be retrieved in either plot or tabular formats. Intermittent data from the groundwater monitoring program is stored in a separate system and can be retrieved as a data listing.

Sections Two and Three discuss the quantity and quality monitoring needs for rainfall and runoff respectively. Included in these sections are recommendations for quantity monitoring frequency and quality sampling and analysis.

Section Four discusses the current water level monitoring program for city ponds and includes recommendations for its modification. The extensive existing groundwater monitoring well network is discussed in Section Five and comments and observations are offered for consideration by the City of Tampa regarding its expansion and monitoring frequency.

# SECTION 2

# RAINFALL

The City's rainfall monitoring network presently consists of eight rainfall gages located throughout Tampa. Seven of these gages are owned and operated by the City and the eighth gage, located at Tampa International Airport, is owned and operated by a private contractor for the National Oceanic and Atmospheric Administration.

Tampa's existing citywide rain gage network is shown in Figure 1. The network is superimposed over a map which indicates drainage problems that have been identified in the City. The effective areas for each of the rain gages is shown by means of delineating the Thiessen polygons associated with each gage. Examination of the existing network indicates two interesting features:

- The number of identified drainage problems per Thiessen polygon is much greater in the northern portion of the City than it is in either the central section or the western section even though the area per polygon is considerably smaller.

- The western-most rain gages are located along the north-south axis which coincides with 30th Street. Rainfall data for all sites in the southeastern portion of the City is based on rain gages which are centrally located within the City limits.

Alternative rain gage locations were examined in an attempt to improve the existing City network without adding additional gages. Both the drainage problem density for Thiessen polygon and the location of the western most rain gages could be improved by relocating only two gages. The first relocation would be to remove the existing gage in Lowry Park and relocate it approximately 2.5 miles south at the Department of Sanitary Sewers pump station located on the eastern bank of the Hillsborough River between Buffalo and Columbus Avenues. The second relocation is the existing gage at the 12th Street yard to the site of the City's Solid Waste Recovery Facility which is located approximately 1.6 miles east. The impact of these relocations is shown in Figure 2.

Both the existing City network and the proposed alternative network contain a total of eight rain gages which leaves the City with one additional rain gage that can be utilized for special studies and located as required. Two additional reliable rain gages have been identified in an effort to expand the ability of

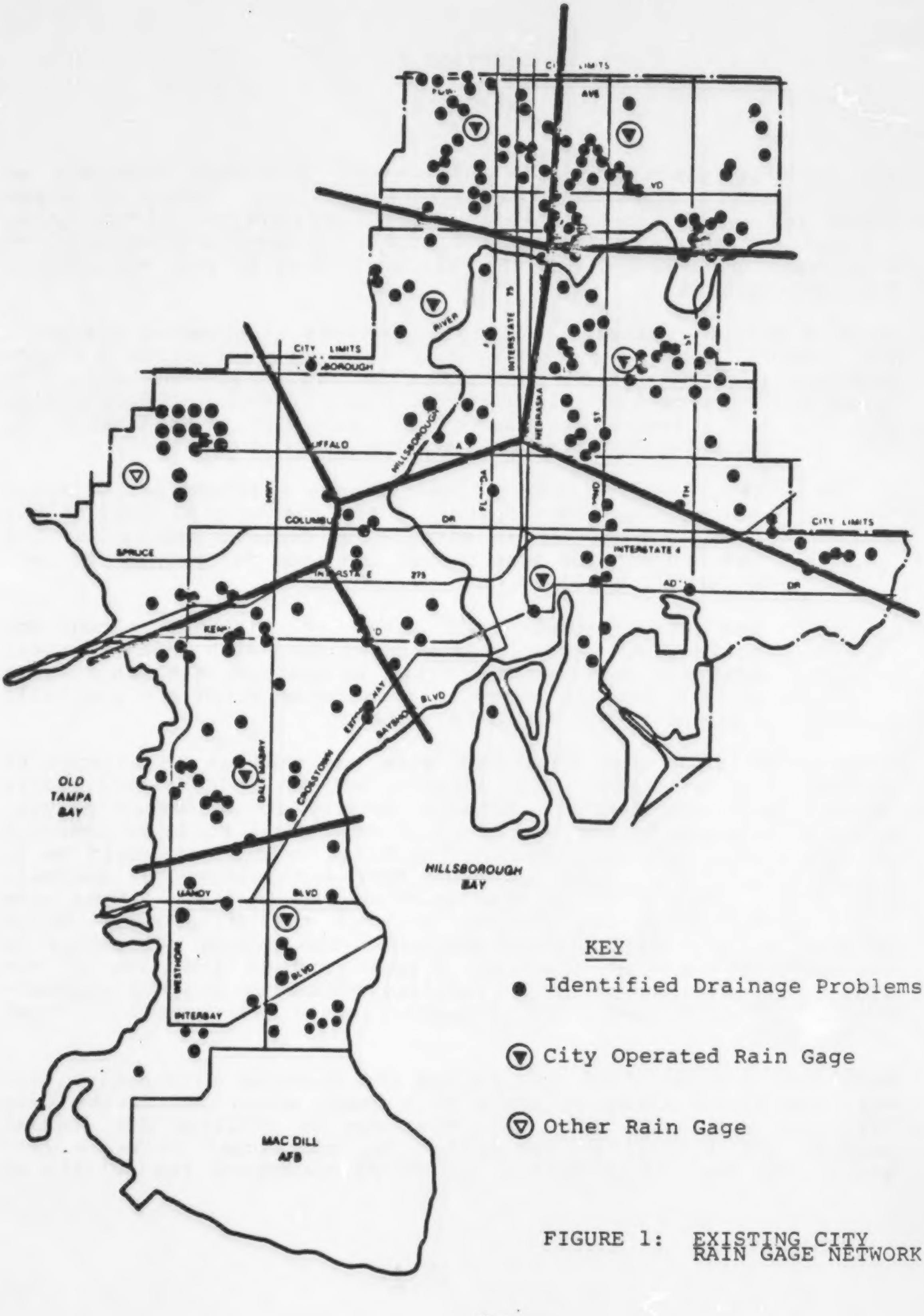

CITY LIMITS
AVE
VD
RIVER
INTERSTATE 75
CITY LIMITS
BOROUGH
UFFALO
HILLSBOROUGH
NEBRASKA
ST
HWY
COLUMBUS
DR
SPRUCE
INTERSTATE 4
CITY LIMITS
INTERSTATE 275
DR
KENN
EXPRESSWAY
BAYSHORE BLVD
CROSSTOWN
DALE MABRY
OLD TAMPA BAY
HILLSBOROUGH BAY
GANDY
BLVD
WESTSHORE
BLVD
INTERBAY
MAC DILL AFB
KEY
● Identified Drainage Problems
City Operated Rain Gage
Other Rain Gage

FIGURE 1: EXISTING CITY RAIN GAGE NETWORK

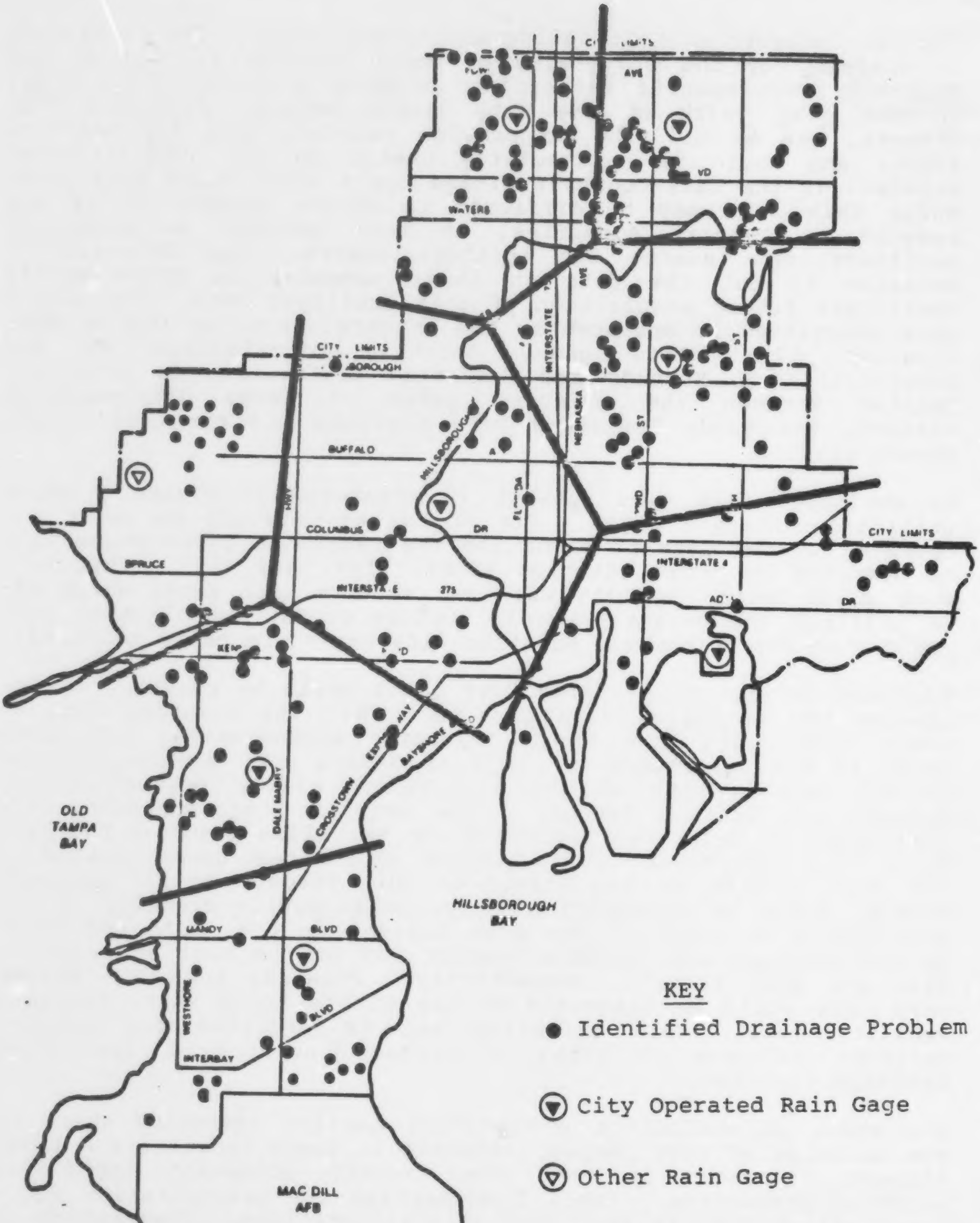

CITY LIMITS
AVE
VD
WATERS
CITY LIMITS
BOROUGH
BUFFALO
HILLSBOROUGH
HWY
COLUMBUS
DR
SPRUCE
INTERSTATE 275
INTERSTATE
NEBRASKA
AVE
ST
CITY LIMITS
INTERSTATE 4
DR
KEN
OLD TAMPA BAY
DALE MABRY
CROSSTOWN
EXPRESSWAY
BAYSHORE BLVD
HILLSBOROUGH BAY
GANDY
BLVD
WESTSHORE
BLVD
INTERBAY
MAC DILL AFB
KEY
● Identified Drainage Problem
City Operated Rain Gage
Other Rain Gage

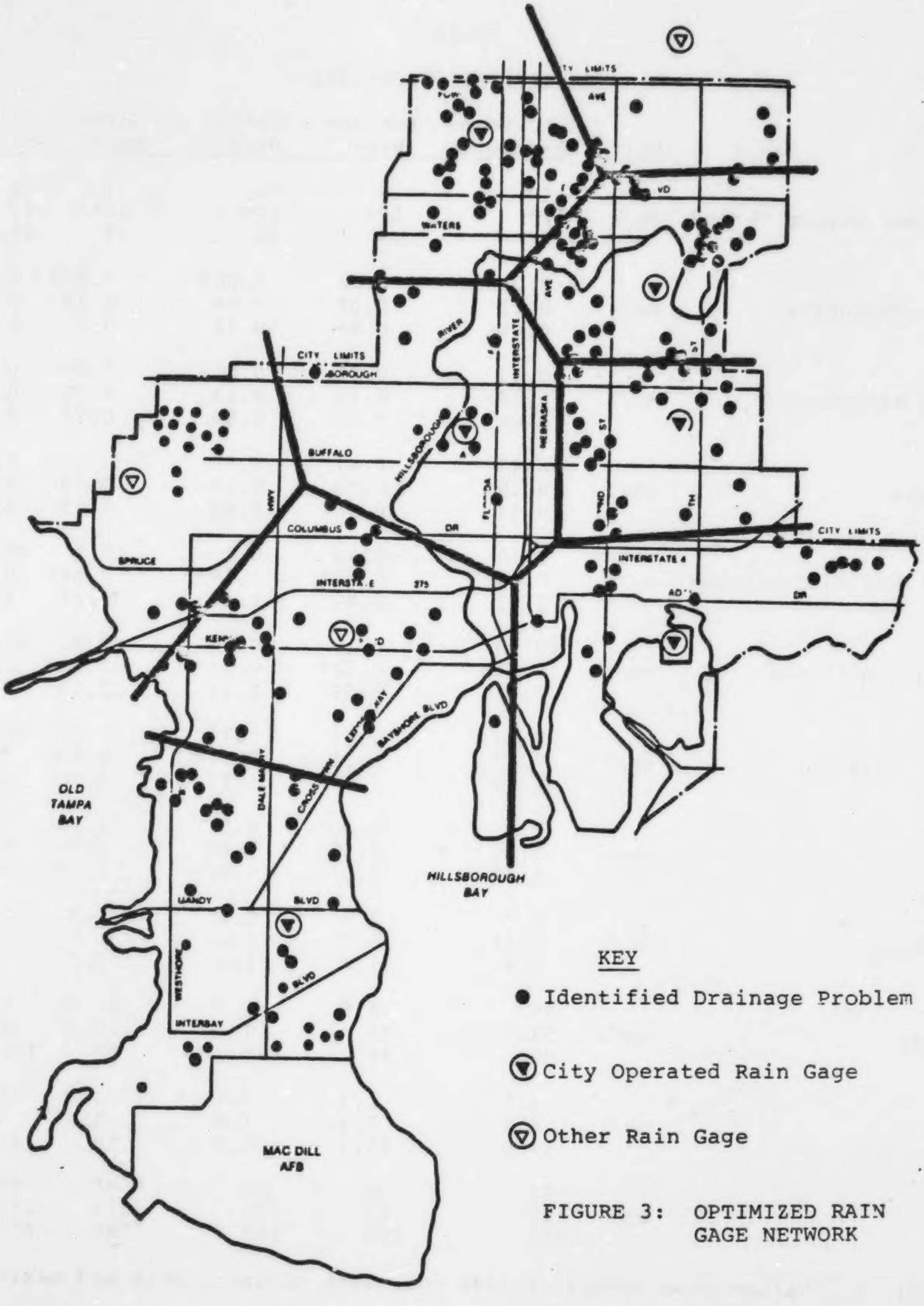
FIGURE 2: ALTERNATIVE RAIN GAGE NETWORK

the City network without adding additional costs. The first gage is operated by the University of South Florida as part of the Geography Department's meteorology studies program. This gage, located just north of the City limits between 22nd and 50th Streets, can be utilized to provide rainfall data for northern Tampa, and would be particularly useful in the evaluation of rainfall in the City-County drainage basin which feeds Duck Pond. While this data may be difficult to obtain because it is not reduced to tabular summaries, it does provide an excellent ancillary data source for critical events. The University's decision to put the data in their computer in FY'84 should facilitate future acquisition of this ancillary data. The second gage identified is operated by the meteorological service of WTVT (Channel 13). This gage, located approximately at the intersection of Kennedy and Henderson Boulevards, is centrally located between the existing gages at Tampa International Airport, the Gandy Boulevard Fire Station, and the City's 12th Street yard.

An optimized rain gage network is presented in Figure 3 which utilizes nine rain gages. Six of the gages would be owned and operated by the City of Tampa and the remaining three gages will be operated by other entities (NOAA, WTVT, and USF). This network would leave the City with two reserve rain gages which can be utilized for basins specific studies or for substitution purposes when any of the six existing City gages are being repaired.

Four relocations of existing City gages would be required to implement the optimized rain gage network. The existing gage at Lowry Park would have to be relocated approximately 2.5 miles south at the Department of Sanitary Sewers pump station located on the eastern bank of the Hillsborough River between Hillsborough and Buffalo Avenues. The existing gage at Poinsettia Lake would be relocated approximately two miles south at the City Water Treatment Plant. The existing 30th Street gage, located at the fire station on the corner of 30th Street and Hillsborough Avenue, would be relocated to a piece of public property in the approximate centroid of the area bounded on the north and south by Hillsborough and Buffalo Avenues and on the west and east by 22nd and 40th Streets, respectively. Finally, the 12th Street yard gage would be relocated at the City's Solid Waste Recovery Facility site. This optimized network provides for smaller Thiessen pologons in areas of higher densities of identified drainage problems.

The Phase II evaluation of rainfall quality indicated that, to the surprise of many people, rainfall in Tampa represents a significant component of the urban runoff pollutant loads for selected parameters. Table 1 summarizes the precipitation quality findings for the four NURP rainfall stations. Examination of this tables indicates that quality characteristics were highly


CITY LIMITS
AVE
WATERS
VD
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INTERSTATE
AVE
CITY LIMITS
BOROUGH
BUFFALO
HILLSBOROUGH
NEBRASKA
ST
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FLORIDA
HWY
COLUMBUS
DR
TH
CITY LIMITS
SPRUCE
INTERSTATE 4
INTERSTATE 275
DR
KENN
DALE MABRY
CROSSTOWN
EXPRESSWAY
BAYSHORE BLVD
OLD TAMPA BAY
HILLSBOROUGH BAY
GANDY
BLVD
WESTSHORE
BLVD
INTERBAY
MAC DILL AFB
KEY
● Identified Drainage Problem
City Operated Rain Gage
Other Rain Gage

FIGURE 3: OPTIMIZED RAIN GAGE NETWORK

## TABLE 1

## PRECIPITATION QUALITY

|  | Unit | J.L. Young Apartment | Horizon Park | Charter & Harding | Norma Park | All Stations |
|---|---|---|---|---|---|---|
| Chemical Oxygen Demand | mg/l | 4<br>12*<br>23 | 5<br>17*<br>49 | <1<br>17*<br>38 | 3<br>20*<br>43 | <1<br>17<br>49 |
| Ortho-Phosphate | mg/l | <0.014<br>0.13*<br>0.056 | 0.01<br>0.05<br>0.09 | 0.003<br>0.04<br>0.11 | 0.003<br>0.19<br>0.37 | 0.003<br>0.10<br>0.056 |
| Total Phosphate | mg/l | <0.02<br>0.16*<br>0.62 | 0.01<br>0.10<br>0.21 | 0.026<br>0.13<br>0.50 | 0.036<br>0.23<br>0.70 | 0.01<br>0.16<br>0.70 |
| Nitrate | mg/l | 0.13<br>0.19<br>0.34 | 0.11<br>0.24<br>0.58 | 0.08<br>0.24<br>0.40 | 0.135<br>0.30<br>0.70 | 0.08<br>0.24<br>0.70 |
| Total Kjeldahl Nitrogen | mg/l | 0.10<br>0.34*<br>1.31 | <0.13<br>0.38*<br>0.85 | <0.1<br>0.55*<br>1.44 | <0.1<br>0.54*<br>2.22 | <0.1<br>0.45<br>2.22 |
| Organic Nitrogen | mg/l | <0.10<br>0.34*<br>1.31 | <0.10<br>0.34*<br>0.56 | <0.10<br>0.53*<br>1.44 | <0.01<br>0.48*<br>2.22 | <0.01<br>0.42<br>2.22 |
| Total Nitrogen | mg/l | 0.13<br>0.51<br>1.48 | 0.37<br>1.23<br>4.78 | <0.1<br>0.77*<br>1.72 | 0.22<br>0.82<br>2.36 | <0.1<br>0.83<br>4.78 |
| pH | ---- | 5.0<br>5.46<br>6.70 | 5.30<br>5.65<br>6.00 | 4.81<br>5.40<br>6.50 | 4.95<br>6.01<br>7.05 | 4.81<br>5.63<br>7.05 |
| Cadmium | ug/l | 0.2<br>0.55<br>0.9 | 0.3<br>0.7<br>1.4 | 0.5<br>1.5<br>3.6 | 0.3<br>1.0<br>2.0 | 0.2<br>0.94<br>3.6 |
| Copper | ug/l | 25<br>53<br>98 | 6.6<br>32<br>86 | 16<br>50<br>103 | 13.3<br>24.5<br>50 | 6.6<br>39.9<br>103 |
| Lead | ug/l | 3.1<br>6.7<br>14.2 | 2.3<br>7.3<br>10.8 | 2.0<br>3.8<br>5.3 | 2<br>5.6<br>10 | 2<br>5.85<br>14.2 |
| Zinc | ug/l | 65<br>189<br>400 | 30<br>92<br>195 | 60<br>183<br>360 | 85<br>119<br>180 | 30<br>145.8<br>400 |

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NOTES: 1. Values presented in triads represent minimum, mean and maximum values.

2. Values noted with an astrick (*) indicate that mean values were calculated using limit values for parameters reported as "less than" a specific analytical limit.

variable at the four stations just as the precipitation quantity is highly variable within the City.

A precipitation quality monitoring program is recommended for implementation in the City of Tampa. The objective of this program is to document areal and seasonal variability and precipitation quality characteristics. It is recommended that three gages in the optimized rain gage network be utilized for this analysis. The following considerations are recommended in the establishment of this program.

- Sampling Frequency -- stations should be sampled five times per year, essentially quarterly with two samples during the wet season (one early and one late in the season) with sampling dates selected to include samples representative of: winter frontal movement in the period of December through early March; dry spring weather in the period of mid-March through late May; and, convective thundershower activity during the summer months of the wet season.
- Stations -- precipitation quality samples should be collected at three stations including: Seneca; Interbay; and the Solid Waste Recovery Facility site. While the Solid Waste Recovery Facility Site may be subject to particulate fallout once the new facility is in operation (after covering of existing ash piles with soil), it should be representative of areas of the City which are downwind of the facility and subject to particulate fallout (downtown, Davis Island, etc.).
- Sample Type -- samples collected should be representative of bulk rainfall including wetfall and dryfall components and should be cumulative samples for one event (collector size should be larger enough to accumulate adequate sample with a 0.3-0.6 inch rainfall).
- Parameters -- the rainfall sample collected should be analyzed with the following chemical parameters: chemical oxygen demand, ortho-phosphate, total-phosphate, nitrate, total kjeldahl nitrogen, organic nitrogen, total nitrogen, pH, cadmium, copper, lead, and zinc.

# SECTION 3

## STORMWATER RUNOFF

The City presently operates four streamflow stations which are utilized to monitor stormwater runoff and base flow from large catchments and major basins. Three of these sites are utilized to document flows at points where runoff is discharged into (Twin Lakes and Duck Pond) and out of (Henry Ditch) City boundaries from or to Hillsborough County. In addition to these stations, the City cooperates with the U.S. Geological Survey in the operation of two surface water flow monitoring stations (29th Street Outfall and Sulphur Springs). The general location of these six stations is shown in Figure 4 which also shows the location of the seven NURP stations which have been removed from service as of the date of this document.

As a result of the Tampa NURP Study, the City has at its disposal seven additional flow monitoring and recording instruments. These instruments can be utilized in conjunction with a standard primary section for direct flow measurements or can be utilized to record stage in a channel for later use with a stage:discharge curve. These instruments represent a valuable City resource when operated in either mode.

The Phase II NURP investigations indicated that eight of the major drainage basins which are tributary to the Lower Hillsborough River have significant flooding problems including: Forrest Hills, Seaboard Coastline, Tampa Heights, Hillsborough Avenue, North Tampa, West Tampa, Seminole Heights, and Kirby Creek. The Stormwater Management Division has already begun making basinwide drainage studies of major basins experiencing flooding in Tampa on a prioritized basis.

A consideration in the use of the monitoring equipment is long-term vs short-term applications. Short-term application for data collection for specific planning studies should be designated as the present use of the equipment. While data for the planning studies are being collected, the City should begin the formulation of goals and objectives for a long-term flow monitoring program. The specific need for this program will be based on permit requirements for stormwater outfalls to receiving waters, the defensible need for long-term data at critical points in the storm sewer network, and engineering data base needs created by the (soon to be implemented) drainage utility. At present, the City should concentrate its flow monitoring activities on the short-term data needs of the basins with indicated significant drainage problems.

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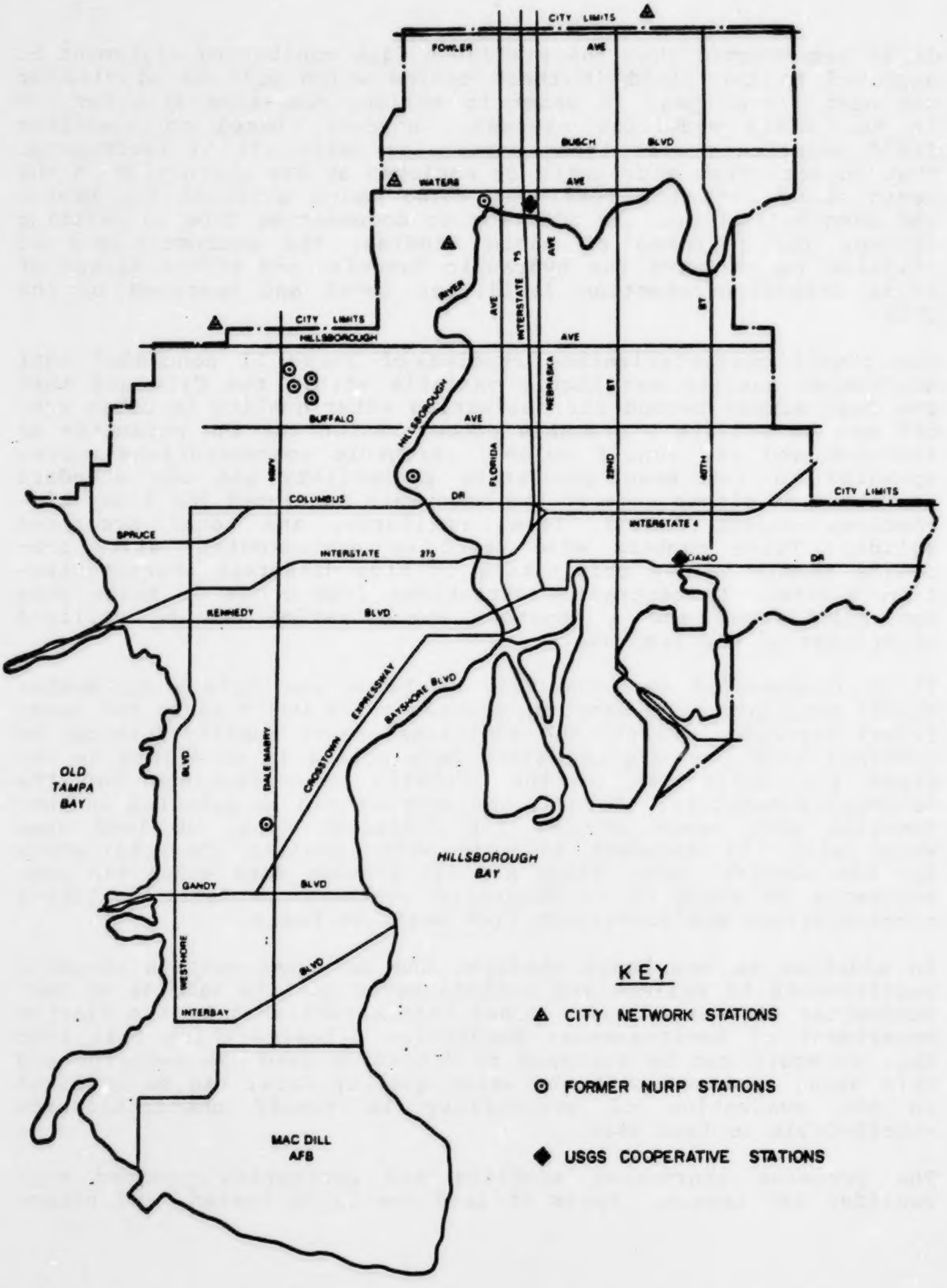
CITY LIMITS
FOWLER AVE
BUSCH BLVD
WATERS AVE
INTERSTATE 75
FLORIDA AVE
NEBRASKA AVE
22ND ST
40TH ST
CITY LIMITS
HILLSBOROUGH AVE
HILLSBOROUGH RIVER
BUFFALO AVE
ARMENIA
COLUMBUS DR
CITY LIMITS
INTERSTATE 4
SPRUCE
INTERSTATE 275
ADAMO DR
KENNEDY BLVD
CROSSTOWN EXPRESSWAY
BAYSHORE BLVD
DALE MABRY
BLVD
OLD TAMPA BAY
HILLSBOROUGH BAY
GANDY BLVD
WESTSHORE BLVD
INTERBAY BLVD
MAC DILL AFB
KEY
▲ CITY NETWORK STATIONS
◎ FORMER NURP STATIONS
◆ USGS COOPERATIVE STATIONS

FIGURE 4
EXISTING CITY FLOW
MEASUREMENT NETWORK

It is recommended that the available flow monitoring equipment be deployed in the field in those basins which will be studied in the next fiscal year in order to collect real-time data for use in the basin modelling process. However, based on operating field experience with these particular units, it is recommended that no more than four units be employed at any given time in the basin study with the remaining three being utilized for backup and cannibalization. In addition to documenting flow in existing systems for purposes of basin studies, the equipment can be utilized to evaluate the hydraulic function and effectiveness of major detention/retention facilities owned and operated by the City.

The runoff characterization studies of Phase II concluded that stormwater quality was highly variable within the City and that the best simple method for estimating water quality in urban runoff was to utilize a probable concentration for the parameter of interest and the runoff volume. Probable concentrations corresponding to the mean cumulative probability and one standard deviation on either side of the mean were developed for 5-day biochemical oxygen demand, fecal coliforms, and total suspended solids. These numbers were based on approximately sixty composite sample values originating in five different characterization basins. Concentration variations from basin to basin were not significant and a constant concentration can be utilized regardless of the land use.

It is recommended that the City of Tampa institute a stormwater runoff monitoring and sampling program which would serve two beneficial purposes. First, the additional water quality data can be combined with the original sixty data points in an effort to improve the definition of the probable concentrations for the selected parameters. Second, the samples can be selected in conjunction with basin studies for different types of land uses which will (1) document specific water quality characteristics for the basin(s) under study and (2) provide data which can subsequently be analyzed to determine whether, in fact, pollutant concentrations are consistent from basin to basin.

In addition to new basin studies, the City has certain on-going requirements to collect and analyze water quality samples to meet stormwater discharge permit conditions established by the Florida Department of Environmental Regulation. Basins which fall into this category can be analyzed to determine land use patterns and this data, combined with the water quality data, can be utilized in the evaluation of variability in runoff characteristics attributable to land uses.

The proposed stormwater sampling and monitoring program must consider two issues: types of land use to be tested, and nature of the sampling. The land uses targeted for testing will be dictated by short-term data needs for basin planning studies and the nature of the catchment being analyzed. Given that most of the basins in Tampa are characterized by mixed land uses, it would appear reasonable that the City should concentrate on heterogeneous basins and avoid sampling the rare and typical homogenous basins.

Cost of analysis for a single event is another way of describing the nature of the sampling effort. For the purpose of characterizing runoff, it is recommended that the City collect flow-paced composite samples in a single sampler container and analyze the samples as flow composites. This will greatly stretch the number of storms which can be analyzed. For any proposed testing of stormwater management practices (SMPs), it is recommended that the City collect either timed or flow-paced discrete samples using the 24 bottle (1.5 L) sampler racks and that these samples be analyzed individually in order to document temporal variations in discharge quality for SMPs being tested.

It is not recommended at this time that a "pure research" sampling program be instituted in the City to collect "snap shot" data. Rather, it is recommended that the available funding for water quality sampling and analysis be utilized to meet the permit sampling requirements established by the FDER and to compliment the on-going major drainage basin studies.

# SECTION 4

# SURFACE WATER LEVELS

The City of Tampa owns and operates approximately 90 detention/retention facilities as part of the stormwater drainage system. Ponds exist throughout Tampa and account for 374 acres within the City limits or 0.7% of the City area. While lakes sometimes occur naturally due to depression contours or sinkholes, many lakes are manmade and are utilized for stormwater management. Detention/retention pond systems have become a popular method for attenuating stormwater discharges since Tampa established its drainage rules. Pond sizes vary throughout the City over the range of 0.11-35.48 acres with the mean being 3.54 acres. More than half of the ponds are less than two acres in size and better than one third of the ponds are less than one acre in size.

Water level management within these ponds is important for several reasons including: retention capacity for hydraulic reduction, detention capacity for peak flow rate attenuation, and problems associated with weeds and odors. Many of the ponds within the City function as detention ponds and are effected more often by downstream conditions than by controlled discharge requirements.

It is recommended that major facilities which act as retention ponds for larger drainage systems be monitored throughout the wet season. Table 2 was prepared from the retention pond inventory maintained by the O&M Section and represents a list of candidate lakes for water level monitoring based on size and the presence of pump stations. The monitoring of these ponds should provide several major benefits to the City.

First, comparison of long-term level records can be used to indicate loss of downstream capacity due to siltation and sedimentation. Second, as development continues and mean annual wet season levels vary (and probably rise) the levels can be used to indicate the need for upstream volume controls and downstream capacity increases. And finally, larger ponds which have no natural drainage outlet and consequently must be pumped, represent a significant flooding hazard. Monitoring of these lakes during the wet season, and during the ensuing dry season when the water level falls and the pond recovers to its normal levels, will provide an advanced warning as to when emergency pumping may be required to prevent flooding.

Major detention facilities tend to lose hydraulic capacity due to the accumulation of sediment and silt in the bottom of the ponds. These facilities can be monitored to determine their inflow/dis-

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## TABLE 2

## CANDIDATE LAKES FOR WATER LEVEL MONITORING*

| | City Pond Number | Pond Location | Size (acres) | Is Pond Pumped? |
|---|---|---|---|---|
| 1. | B-12-009.1 | 109th & North Boulevard | 1.74 | Yes |
| 2. | B-14-004.1 | East Poinsettia & 27th Street | 3.24 | Yes |
| 3. | B-15-002.1 | Bougainville & 46th Street | 11.10 | No |
| 4. | C-13-002.1 | Elmer Street & 98th Avenue | 2.93 | Yes |
| 5. | C-15-003.1 | 99th Avenue & Greenwood Street | 1.10 | Yes |
| 6. | F-13-051.1 | Chelsea Street & 22nd Street | 9.30 | No |
| 7. | F-14-019.1 | 30th Street South of Osborne | 9.59 | No |
| 8. | G-12-001.1 | Robles Park Pond | 15.67 | Yes |
| 9. | G-14-056.1 | 26th Avenue & 26th Street | 12.70 | No |
| 10. | G-15-040.1 | 37th Street & 26th Avenue | 6.10 | No |
| 11. | G-15-042.1 | 19th Street West of Stallone | 6.00 | No |
| 12. | H-14-058.1 | Columbus Drive & 34th Street | 5.17 | No |
| 13. | J-11-001.1 | Albany Street & Bristol Avenue | 0.76 | Yes |
| 14. | N-09-001.1 | Bobby Hicks Pond | 35.48 | No |

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* Based on city inventory and responsibility

charge characteristics. Periodic assessment of these characteristics can be utilized to indicate when major maintenance for sediment removal or reconstruction is required. It is recommended that a long-term schedule for testing major detention ponds be developed by the Planning Section for use by the O&M Section in assessing maintenance needs and establishing future budgets.

# SECTION 5

## GROUNDWATER LEVELS

The City, through the activities of the Departments of Sanitary Sewers and Public Works, operates an extensive monitoring well network to determine groundwater levels throughout Tampa. The present network consists of 89 individual monitor wells of which 53 are read monthly and 6 are read intermittently. The pattern of the well locations, as shown in Figure 5, is similar to the pattern of identified drainage problems are previously shown in Figure 1.

In consideration of the large number and wide distribution of existing monitoring wells, it is not recommended that any new monitoring wells be installed strictly for the purposes of stormwater management. However, several areas do exist within the City which have very few monitor wells available for groundwater level documentation. These areas include:

- The southern portion of the North Tampa neighborhood bounded by Bougainvilla, 26th Street, Busch Boulevard, and Ashley Street.
- The western portion of the Sulphur Springs neighborhood and the entire Lowry Park neighborhood bounded by Armenia Avenue, Busch Boulevard, Nebraska Avenue, and Hillsborough Avenue.
- The northeastern portion of the Seminole Heights neighborhood bounded by Sligh Avenue, 36th Street, Hillsborough Avenue, and Nebraska Avenue.
- The western portion of the Wellswood neighborhood bounded by Hillsborough Avenue, Florida Avenue, Columbus Drive, and Himes Avenue.
- The majority of the Belmont Heights, North Viewhills, Tampa Heights, College Hill, Jackson Heights, and Myrtle Hill neighborhoods bounded by Hillsborough Avenue, 50th Street, Columbus Avenue, and Nebraksa Avenue.
- The Manhattan and Lower Bayshore neighborhoods bounded by El Prado Boulevard, Bayshore Boulevard, Gandy Boulevard, and Westshore Boulevard.

Twelve new wells have been added in a fairly uniform manner in these six areas for the specific purposes of

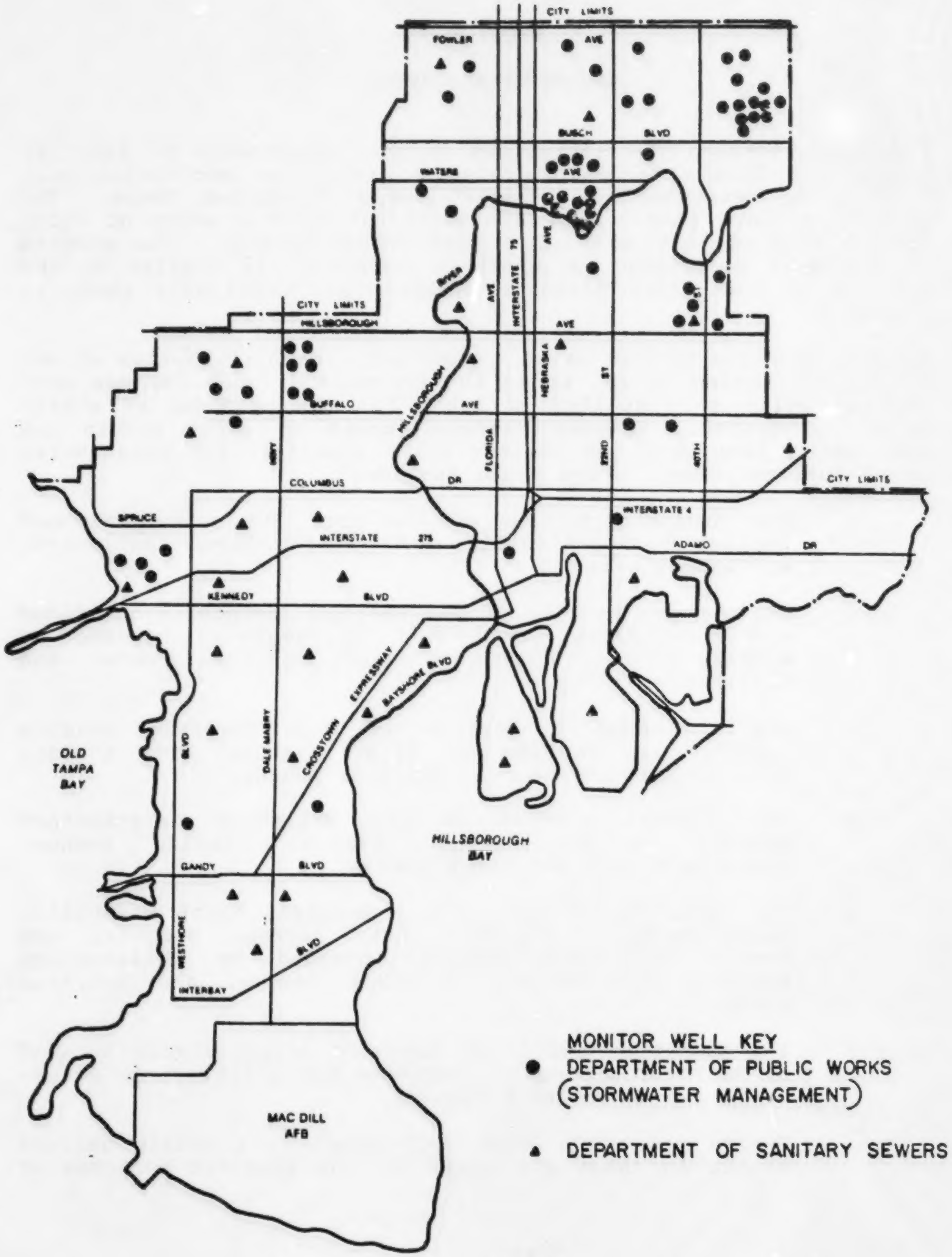
CITY LIMITS
FOWLER AVE
BUSCH BLVD
WATERS AVE
RIVER
AVE
INTERSTATE 75
NEBRASKA AVE
CITY LIMITS
HILLSBOROUGH AVE
BUFFALO AVE
HILLSBOROUGH
FLORIDA
22ND ST
40TH ST
MABRY
COLUMBUS DR
CITY LIMITS
SPRUCE
INTERSTATE 275
INTERSTATE 4
ADAMO DR
KENNEDY BLVD
CROSSTOWN EXPRESSWAY
BAYSHORE BLVD
DALE MABRY
WESTSHORE BLVD
OLD TAMPA BAY
HILLSBOROUGH BAY
GANDY BLVD
INTERBAY BLVD
MAC DILL AFB
MONITOR WELL KEY
● DEPARTMENT OF PUBLIC WORKS (STORMWATER MANAGEMENT)
▲ DEPARTMENT OF SANITARY SEWERS

FIGURE 5
EXISTING CITY
GROUNDWATER NETWORK

increasing network coverage and better water table definition during the period June-August, 1983. However, it is still felt that coverage and definition of these areas could be improved.

In order to accumulate knowledge on groundwater levels and soil characteristics in these identified areas, it is recommended that the City implement an innovative program to acquire additional groundwater wells at minimum cost. Two mechanisms exist for acquiring groundwater monitoring wells in these areas. The first and simplest approach is to examine all municipal construction in these areas which requires soil borings. When soil borings are being conducted for municipal work in any of the areas identified, it is possible to coordinate the placement of those borings such that the boring is located in a manner that it will not be destroyed during the public construction and that it can be subsequently be utilized for groundwater monitoring. Normally, a reputable driller is willing to insert a section of continuously-slotted PVC pipe in the boring hole prior to backfilling at a very nominal cost. City crews can install a protective GIP shroud with a screw-on galvanized iron cap after the slotted PVC has been installed and backfilled. This approach can provide a relatively inexpensive groundwater monitoring well.

The second approach is to coordinate with private developers and/or drainage engineers conducting soils investigations for privately owned drainage facilities. In the case of multiple borings, it is possible to locate one of the borings in the public right-of-way adjacent to the property line. This boring can serve to provide information on soil suitability for drainage/retention facilities and can also, as in the case of municipal construction, provide for an inexpensive groundwater monitoring well. An extension of this thought process would be to require the owners of detention/retention facilities to provide a shallow groundwater monitoring well to enable the monitoring of groundwater levels around their facility.

It has been suggested that the existing groundwater level monitoring network could be used to monitor for groundwater quality. It is recommended that the Stormwater Management Division not undertake this suggestion for the following reasons:

- The construction of many of the monitoring wells is not known and unfortunately this precludes their use for reliable groundwater quality monitoring.
- Chemical analysis of samples represents a significant cost consideration in an overall monitoring program and funds should not be committed without a clearly defined program goal.

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- The reason for quality monitoring establishes the frequency of monitoring and the parameters analyzed. The NURP Program did not evaluate groundwater quality and this prevents the identification of a problem which creates a need for groundwater quality monitoring.

Specific recommendations developed for the groundwater level monitoring network include:

- Wells should be read bi-monthly (January, March, May, July, September, and November) at a minimum to provide definition of temporal and areal variations in water table levels.
- It is strongly recommended that ancillary well level readings be conducted in June and August to better define water level response at individual sites and to supplement the recommended minimum well reading schedule.
- The City should select 20-25 key monitoring wells located strategically throughout the City and develop "period of record" graphic plots which are updated each time the key wells are read. This document should be prepared on a rectangular grid with a long-term time axis (20 years by months, K&E Forms 47-3850 or 47-3853 or equivalent), and will provide the City with a quick, easy method of estimating groundwater levels without extensive analysis of well data in the computer data base.
- The City should collect data on wells for a minimum of six years and then conduct bi-annual analysis of the collected data base on each well. The items analyzed should include:

    1. Elevation mean value and value ranges for
        - Upper 10% of readings
        - Upper 10-50% of readings
        - Middle 80% of readings
        - Middle 70% of readings
        - Lower 10-50% of readings
        - Lower 10% of readings
    2. Maximum Value
    3. Mean Value
    4. Minimum Value
    5. Standard deviation of all values